Selected files

9 printable files

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encoder/utils.py
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ycbcr.py

```python
# Module transforming RGB images into YCbCr
import numpy as np
import numpy.linalg as alg

mat = np.array(
    [[65.481, 128.553, 24.966], [-37.797, -74.203, 112.0], [112.0, -93.786, -18.214]]
)

col = np.array([[16, 128, 128]])


def rgb_to_ycbcr(rgb: tuple) -> tuple:
    a = np.asarray(rgb)
    b = mat.dot(a)
    return tuple(b + col)


def ycbcr_to_rgb(t: tuple) -> tuple:
    a = np.asarray(t)
    b = alg.inv(mat)
    c = a - col
    d = b.dot(c[0])
    return tuple(d)
```

huffman.py

```python
# Module computing Huffman compression


from collections import Counter, namedtuple
from heapq import heapify, heappop, heappush


# Node in a Huffman Tree
Node = namedtuple("Node", ["char", "freq"])
```

```python
class HuffmanCompressor:
    """Huffman compression implementation"""
    def __init__(self):
        self.encoding_table = {}
        self.decoding_table = {}

    def build_tables(self, s: str):
        """create both the encodingn and decoding tables of a given string

    parameters
    ----------
        -s : string used to build the tables

    return
    ------
        - fill both the encoding and decoding table of the given class instance"""

        freq_table = Counter(s)

        # create a heap of the nodes in the tree
        heap = []
        for char, freq in freq_table.items():
            heap.append(Node(char, freq))
        heapify(heap)

        # create the Huffman tree
        while len(heap) > 1:
            left_node = heappop(heap)
            right_node = heappop(heap)
            combined_node = Node(None, left_node.freq + right_node.freq)
            heappush(heap, combined_node)

        def build_encoding_table(node, code=''):
            if node.char is not None:
                # if the node is a leaf, add it to the encoding table
                self.encoding_table[node.char] = code
                return
            # if the node is not a leaf, recursively build the encoding table
            build_encoding_table(node.left, code + '0')
            build_encoding_table(node.right, code + '1')

        build_encoding_table(heap[0])


        def build_decoding_table(node, code=''):
            if node.char is not None:
                # if the node is a leaf, add it to the decoding table
                self.decoding_table[code] = node.char
                return
            # if the node is not a leaf, recursively build the decoding table
            build_decoding_table(node.left, code + "0")
            build_decoding_table(node.right, code + "1")

        build_decoding_table(heap[0])

    def compress(self, s: str) -> str:
        """compress the inputed string
```

```python
        parameters
        ----------
            -s : string to be compressed

        return
        ------
            - compressed string"""
            compressed = ""
            for char in s:
                compressed += self.encoding_table[char]
            return compressed

        def decompress(self, compressed: str) -> str:
            """decompress the inputed string

        parameters
        ----------
            -s : string to be compressed

        return
        ------
            - decompressed string"""
            decompressed = ""
            i = 0
            while i < len(compressed):
                for j in range(i+1, len(compressed)+1):
                    if compressed[i:j] in self.decoding_table:
                        decompressed += self.decoding_table[compressed[i:j]]
                        i = j
                        break

            return decompressed
```

fft.py

```python
# fast-fourier transforms

import complex as cpx
from numpy import log2
from cmath import pi, exp, cos
from scipy.fftpack import dct, idct


def FFT(vector:list) -> list:
    """calculate the fast fourier tranform of a vector

    parameters
    ----------
        -vector : list of Complex object
```

```python
16          return
17          ------
18              - 1-D fast fourier transform of the vector"""
19      n = len(vector)
20      assert log2(n).is_integer(), "make sure that the length of the arguement is a
    power of 2"
21      if n == 1:
22          return vector
23      poly_even, poly_odd = vector[::2] , vector[1::2]
24      res_even, res_odd = FFT(poly_even), FFT(poly_odd)
25      res = [cpx.Complex(0)] * n
26      for j in range(n//2):
27          w_j = cpx.exp_to_literal(-2*pi*j/n)
28          product = w_j * res_odd[j]
29          res[j] = res_even[j] + product
30          res[j + n//2] = res_even[j] - product
31      return res
32
33  def IFFT_aux(vector:list) -> list:
34      """auxiliary function that makes the recursive steps of the IFFT algorithm
35      parameters
36      ----------
37          -vector : list of Complex object
38
39      return
40      ------
41          - partial inverse of the 1-D fast fourier transform of the vector (lack
    the division by n)"""
42      n = len(vector)
43      assert log2(n).is_integer(), "make sure that the length of the arguement is a
    power of 2"
44      if n == 1:
45          return vector
46      poly_even, poly_odd = vector[::2] , vector[1::2]
47      res_even, res_odd = IFFT_aux(poly_even), IFFT_aux(poly_odd)
48      res = [cpx.Complex(0)] * n
49      for j in range(n//2):
50          w_j = cpx.exp_to_literal((2 * pi * j) / n)
51          product = w_j * res_odd[j]
52          res[j] = res_even[j] + product
53          res[j + n//2] = res_even[j] - product
54      return res
55
56  def IFFT(vector:list) -> list:
57      """caclulate the inverse of the fast fourier tranform of a vector (in order to
    have ifft(fft(poly)) == poly)
58
59      parameters
60      ----------
61          -vector : list of Complex object
62
63      return
64      ------
65          - inverse of the 1-D fast fourier transform of the vector"""
66      n = len(vector)
67      res = IFFT_aux(vector)
68      for i in range(n):
69          res[i] = res[i] / cpx.Complex(n)
70      return res
```

```python
def DCT(vector:list, orthogonalize:bool =False, norm="forward"):
    """calculate the one-dimensional type-II discrete cosine tranform of a matrix
    (MAKHOUL) (using the FFT function previously defined)

    parameters
    ----------
        - vector: list of Numerical Object

    return
    ------
        - discrete cosine tranform of the input"""
    N = len(vector)
    temp = vector[ : : 2] + vector[-1 - N % 2 : : -2]
    temp = FFT(temp)
    factor = - pi / (N * 2)
    result = [2 * (val * (cpx.exp_to_literal(i * factor))).re for (i, val) in
    enumerate(temp)]
    if orthogonalize:
        result[0] *= 2 ** (-1 / 2)
    if norm == "ortho":
        result[0] *= (N) **(-1 / 2)
        result[1::] = [(2 / N) ** (1 / 2) * result[i] for i in range(1,
    len(result))]
    return result

def IDCT(vector:list):
    """calculate the one-dimensional "inverse" type-III discrete cosine tranform
    of a matrix (MAKHOUL) (using the FFT function previously defined)

    parameters
    --------
        - vector: list of Numerical Object

    return
    ------
        - type-III discrete cosine tranform of the input"""
    N = len(vector)
    factor = - pi / (N * 2)
    temp = [(cpx.Complex(val) if i > 0 else (cpx.Complex(val) / cpx.Complex(2))) *
    cpx.exp_to_literal(i * factor) for (i, val) in enumerate(vector)]
    temp = FFT(temp)
    temp = [val.re for val in temp]
    result = [None] * N
    result[ : : 2] = temp[ : (N + 1) // 2]
    result[-1 - N % 2 : : -2] = temp[(N + 1) // 2 : ]
    return result

if __name__ == "__main__":
    vectorCpx= [cpx.Complex(5), cpx.Complex(2), cpx.Complex(4), cpx.Complex(8)]
    vector = [5, 2, 4, 8]
    print("DCT : ", DCT(vectorCpx))
    print("inverse + DCT : ", IDCT((DCT(vectorCpx))))
    print("scipy dct :", dct(vector))
    print("scipy + inverse dct: ", dct(idct(vector)))
    print("scipy dct (ortho) : ", dct(vector, norm = "ortho"))
    print("scipy inverse + dct (ortho) : ", idct(dct(vector, norm="ortho"),
    norm="ortho"))
```

complex.py

```python
# Module computing complex numbers
# disclaimer : this class is not made to deal with less than 1e-10 values


from numpy import arctan2, cos, pi, sin, sqrt
from math import isclose
from typing import Union, List


class Complex:
    """Computing complex numbers"""
    def __init__(self, real=0., imaginary=0.):
            self.re = real # round(real, 15)
            self.im = imaginary # round(imaginary,15)
    def __str__(self) -> str:
        if self.im == 0.:
            string = f"{self.re}"
        elif self.re == 0:
            string = f"i({self.im})"
        else:
            string = f"{self.re} + i({self.im})"
        return string
    __repr__ = __str__
    def __eq__(self, other) -> bool:
        return bool(isclose(self.re, other.re) and isclose(self.im, other.im))
    def is_null(self):
        return isclose(self.re, 0) and isclose(self.im, 0)
    def is_real(self):
        return isclose(self.im, 0)
    def is_imaginary(self):
        return isclose(self.re, 0)
    def arg(self):
        """return the argument of the complex number
        return None if 0"""
        if self.is_null():
            arg = None
        elif isclose(self.re, 0) and self.im > 0:
            arg = pi / 2
        elif isclose(self.re, 0) and self.im < 0:
            arg = - pi / 2
        else:
            arg = round(arctan2(self.im, self.re), 15)
        return arg
    def module(self):
        """return the module of the complex number"""
        return round(sqrt(self.re**2 + self.im**2), 15)
    def conjuagate(self):
        return (Complex(self.re, -self.im))
    #arithmetic
    def __add__(self, other):
        return Complex(self.re + other.re, self.im + other.im)
    def __sub__(self, other):
        return Complex(self.re - other.re, self.im - other.im)
    def __mul__(self, other):
        real = (self.re * other.re) - (self.im * other.im)
```

```python
            imaginary = (self.re * other.im) + (self.im * other.re)
            return Complex(real, imaginary)
    def __truediv__(self, other):
        if other.is_null():
            raise ValueError("Error : dividing by 0")
        elif other.is_real():
            return Complex(self.re / other.re, self.im / other.re)
        else:
            denominator = (other.re ** 2) + (other.im ** 2)
            real = ((self.re * other.re) + (self.im * other.im)) / denominator
            imaginary = ((self.im * other.re) - (self.re * other.im)) /
denominator
            return Complex(real, imaginary)

Num = Union[int, float]

def addition(*complexes:Complex) -> Complex: #partially depreciated (can still be
usefull for more iterable arguments)
    """calculate the sum of complex numbers

    parameters
    ----------
        - *complexes : iterable type of Complex

    return
    ------
        - sum of the complex numbers"""

    res = Complex(0)
    for number in complexes:
        res.re += number.re
        res.im += number.im
    return res

def difference(cpx1:Complex, cpx2:Complex = Complex(0)): #fully depreciated
(replaced by __sub__ Complex methods)
    """calculate the difference of two complex numbers

    parameters
    ----------
        - cpx1 : Complex number
        - cpx2 : Complex number to subtract to cpx1 (=Complex(0) by default)

    return
    ------
        -   difference of the two complex numbers"""
    res = Complex()
    res.re = cpx1.re - cpx2.re
    res.im = cpx1.im - cpx2.im
    return res

def product(*complexes:Complex) -> Complex: #partially depreciated (can still be
usefull for more iterable arguments)
    """calculate the product of complex numbers

    parameters
    ----------
        - *complexes : iterable type of Complex
```

```python
111        return
112        ------
113            - product of the complex numbers"""
114        res = Complex(1)
115        for number in complexes:
116            re = res.re * number.re - res.im * number.im
117            im = res.re * number.im + res.im * number.re
118            res.re = re
119            res.im = im
120        return res
121
122    def exp_to_literal(arg:float, module:float = 1.0) -> Complex:
123        """ return the literal expression of a complex number defined by its argument
       and module
124
125        parameters
126        ----------
127            - arg : type(float) (should be between 0 and 2pi)
128            - module : type(float) (must have a positive value)(=1 by default)
129
130        return
131        ------
132            - Complex number associated"""
133        assert(module >= 0), "second-argument(module) must have a positive value"
134        return Complex(module*cos(arg), module*sin(arg))
135
136    def nth_root(n:int, cpx:Complex = Complex(1)) -> Complex:
137        """"calculate the nth root of a complex number
138
139        parameters
140        ----------
141            - n : type(int)
142            - complex : type(Complex) (=Complex(1) by default) (must not be
       Complex(0))
143
144        return
145        ------
146            - list of the nth roots"""
147        assert(cpx.re != 0 or cpx.im != 0), "second argument must be a non-zero
       complex number"
148        module = cpx.module()
149        arg = cpx.arg()
150        if arg is not None:
151            return exp_to_literal((arg/n), module**(1/n))
152        else:
153            return Complex(1) #Not used case but just here to ensure nth_root cannot
       return None
154
155
156    def nth_roots_unity(n:int) -> list:
157        """ calculate the n roots of unity
158
159        parameter
160        ---------
161            - n : type(int) : must be a positive integer
162
163        return
164        ------
165            - a list of Complex containing the n roots of unity"""
```

```python
        roots = [Complex(1) for i in range(n)]
        for k in range(0,n):
            roots[k] = exp_to_literal((2*k*pi/n), 1.0)
        return roots

    def inverse_nth_roots_unity(n:int) -> list:
        """ calculate the inversed n roots of unity

        parameter
        ---------
        - n : type(int) : must be a positive integer

        return
        ------
        - a list of Complex containing the inversed n roots of unity"""
        roots = [Complex(1) for i in range(n)]
        for k in range(0,n):
            roots[k] = exp_to_literal((-2*k*pi/n), 1.0)
        return roots

    def make_complex(values:List[Num]) -> List[Complex]:
        res = []
        for value in values:
            res.extend([Complex(value)])
        return res


    if __name__ == "__main__":
        pass
```

arithmetic_coding.py

```python
    def proba(data):
        """
        Créer le dictionnaire de probabilités d'apparition des différents caractères
        """
        assert len(data) != 0
        d = {}
        for x in data:
            d[x] = d.get(x, 0) + (1 / len(data))
        return d


    def create_int(data):
        """
        Créer le dictionnaire des intervalles des différents caractères connaissant
    les données
        """
        p = proba(data)
        d = {}
        n = 0.0
        for c, v in p.items():
            d[c] = (n, n + v)
            n += v
```

```python
        return d


def create_int2(p):
    """
    Créer le dictionnaire des intervalles des différents caractères connaissant
    les probas des différents caractères
    """
    d = {}
    n = 0.0
    for c, v in p.items():
        d[c] = (n, n + v)
        n += v
    return d


def encode(data):
    """
    effectue l'encodage des données
    """
    int = create_int(data)
    value = (0.0, 1.0)
    for x in data:
        d = value[1] - value[0]
        sup = value[0] + d * int[x][1]
        inf = value[0] + d * int[x][0]
        value = (inf, sup)
    return (value[0] + value[1]) / 2


def appartient(x, int):
    """
    teste l'appartenance de x à un intervalle fermé à gauche et ouvert à droite
    """
    assert len(int) == 2
    return x >= int[0] and x < int[1]


def inverse(dic):
    """
    renvoie le dictionnaire où les clés et valeurs sont inversées
    """
    d = {}
    for c, v in dic.items():
        d[v] = c
    return d


def decode(n, p, nbr_carac):
    d = inverse(create_int2(p))
    res = []
    i = n
    while len(res) < nbr_carac:
        for c, v in d.items():
            if appartient(i, c):
                res.append(v)
                i = (i - c[0]) / (c[1] - c[0])
                break
    return res
```

```
 80
 81
 82  # Examples
 83
 84  if __name__ == "__main__":
 85      print(encode("WIKI"))
 86      print(decode(0.171875, {"W": 0.25, "I": 0.5, "K": 0.25}, 4))
 87      print(encode("AAABBCCCCC"))
 88      print(decode(0.010783125000000005, {"A": 0.3, "B": 0.2, "C": 0.5}, 10))
 89      print(encode([1, 2, 3, 4, 5, 6, 7, 8, 9, 10]))
 90      print(
 91          decode(
 92              encode([1, 2, 3, 4, 5, 6, 7, 8, 9, 10]),
 93              {
 94                  1: 0.1,
 95                  2: 0.1,
 96                  3: 0.1,
 97                  4: 0.1,
 98                  5: 0.1,
 99                  6: 0.1,
100                  7: 0.1,
101                  8: 0.1,
102                  9: 0.1,
103                  10: 0.1,
104              },
105              10,
106          )
107      )
108
```

encoder/utils.py

```python
 1  import numpy as np
 2  import math
 3  import cv2
 4  from io import BytesIO
 5
 6
 7  # DCT block size
 8  BH, BW = 8, 8
 9
10
11  class MARKER:
12      SOI = b"\xff\xd8"
13      APP0 = b"\xff\xe0"
14      APPn = (b"\xff\xe1", b"\xff\xef")   # n=1~15
15      DQT = b"\xff\xdb"
16      SOF0 = b"\xff\xc0"
17      DHT = b"\xff\xc4"
18      DRI = b"\xff\xdd"
19      SOS = b"\xff\xda"
20      EOI = b"\xff\xd9"
21
22
```

```python
class ComponentInfo:
    def __init__(self, id_, horizontal, vertical, qt_id, dc_ht_id, ac_ht_id):
        self.id_ = id_
        self.horizontal = horizontal
        self.vertical = vertical
        self.qt_id = qt_id
        self.dc_ht_id = dc_ht_id
        self.ac_ht_id = ac_ht_id

    @classmethod
    def default(cls):
        return cls.__init__(*[0 for _ in range(6)])

    def encode_SOS_info(self):
        return int2bytes(self.id_, 1) + int2bytes(
            (self.dc_ht_id << 4) + self.ac_ht_id, 1
        )

    def encode_SOF0_info(self):
        return (
            int2bytes(self.id_, 1)
            + int2bytes((self.horizontal << 4) + self.vertical, 1)
            + int2bytes(self.qt_id, 1)
        )

    def __repr__(self):
        return (
            f"{self.id_}: qt-{self.qt_id}, ht-(dc-{self.dc_ht_id}, "
            f"ac-{self.ac_ht_id}), sample-{self.vertical, self.horizontal} "
        )


class BitStreamReader:
    """simulate bitwise read"""

    def __init__(self, bytes_: bytes):
        self.bits = np.unpackbits(np.frombuffer(bytes_, dtype=np.uint8))
        self.index = 0

    def read_bit(self):
        if self.index >= self.bits.size:
            raise EOFError("Ran out of element")
        self.index += 1
        return self.bits[self.index - 1]

    def read_int(self, length):
        result = 0
        for _ in range(length):
            result = result * 2 + self.read_bit()
        return result

    def __repr__(self):
        return f"[{self.index}, {self.bits.size}]"


class BitStreamWriter:
    """simulate bitwise write"""
```

```python
    def __init__(self, length=10000):
        self.index = 0
        self.bits = np.zeros(length, dtype=np.uint8)

    def write_bitstring(self, bitstring):
        length = len(bitstring)
        if length + self.index > self.bits.size * 8:
            arr = np.zeros((length + self.index) // 8 * 2, dtype=np.uint8)
            arr[: self.bits.size] = self.bits
            self.bits = arr
        for bit in bitstring:
            self.bits[self.index // 8] |= int(bit) << (7 - self.index % 8)
            self.index += 1

    def to_bytes(self):
        return self.bits[: math.ceil(self.index / 8)].tobytes()

    def to_hex(self):
        length = math.ceil(self.index / 8) * 8
        for i in range(self.index, length):
            self.bits[i] = 1
        bytes_ = np.packbits(self.bits[:length])
        return " ".join(f"{b:2x}" for b in bytes_)


class BytesWriter(BytesIO):
    def __init__(self, *args, **kwargs):
        super(BytesWriter, self).__init__(*args, **kwargs)

    def add_bytes(self, *args):
        self.write(b"".join(args))


def bytes2int(bytes_, byteorder="big"):
    return int.from_bytes(bytes_, byteorder)


def int2bytes(int_: int, length):
    return int_.to_bytes(length, byteorder="big")


def decode_2s_complement(complement, length) -> int:
    if length == 0:
        return 0
    if complement >> (length - 1) == 1:  # sign bit equal to one
        number = complement
    else:  # sign bit equal to zero
        number = 1 - 2**length + complement
    return number


def encode_2s_complement(number) -> str:
    """return the 2's complement representation as string"""
    if number == 0:
        return ""
    if number > 0:
        complement = bin(number)[2:]
    else:
```

```python
            length = int(np.log2(-number)) + 1
            complement = bin(number - (1 - 2**length))[2:].zfill(length)
        return complement


def load_quantization_table(quality, component):
    # the below two tables was processed by zigzag encoding
    # in JPEG bit stream, the table is also stored in this order
    if component == "lum":
        q = np.array(
            [
                16,
                11,
                12,
                14,
                12,
                10,
                16,
                14,
                13,
                14,
                18,
                17,
                16,
                19,
                24,
                40,
                26,
                24,
                22,
                22,
                24,
                49,
                35,
                37,
                29,
                40,
                58,
                51,
                61,
                60,
                57,
                51,
                56,
                55,
                64,
                72,
                92,
                78,
                64,
                68,
                87,
                69,
                55,
                56,
                80,
                109,
                81,
```

```python
                        87,
                        95,
                        98,
                        103,
                        104,
                        103,
                        62,
                        77,
                        113,
                        121,
                        112,
                        100,
                        120,
                        92,
                        101,
                        103,
                        99,
                ],
                dtype=np.int32,
            )
        elif component == "chr":
            q = np.array(
                [
                        17,
                        18,
                        18,
                        24,
                        21,
                        24,
                        47,
                        26,
                        26,
                        47,
                        99,
                        66,
                        56,
                        66,
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                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                        99,
                    ],
                    dtype=np.int32,
                )
        else:
            raise ValueError(
                (
                    f"component should be either 'lum' or 'chr', "
                    f"but '{component}' was found."
                )
            )
        if 0 < quality < 50:
            q = np.minimum(np.floor(50 / quality * q + 0.5), 255)
        elif 50 <= quality <= 100:
            q = np.maximum(np.floor((2 - quality / 50) * q + 0.5), 1)
        else:
            raise ValueError("quality should belong to (0, 100].")
        return q.astype(np.int32)


def zigzag_points(rows, cols):
    # constants for directions
    UP, DOWN, RIGHT, LEFT, UP_RIGHT, DOWN_LEFT = range(6)

    move_func = {
        UP: lambda p: (p[0] - 1, p[1]),
        DOWN: lambda p: (p[0] + 1, p[1]),
        LEFT: lambda p: (p[0], p[1] - 1),
        RIGHT: lambda p: (p[0], p[1] + 1),
        UP_RIGHT: lambda p: move(UP, move(RIGHT, p)),
```

```
                DOWN_LEFT: lambda p: move(DOWN, move(LEFT, p)),
        }

        # move the point in different directions
        def move(direction, point):
            return move_func[direction](point)

        # return true if point is inside the block bounds
        def inbounds(p):
            return 0 <= p[0] < rows and 0 <= p[1] < cols

        # start in the top-left cell
        now = (0, 0)

        # True when moving up-right, False when moving down-left
        move_up = True
        trace = []

        for i in range(rows * cols):
            trace.append(now)
            if move_up:
                if inbounds(move(UP_RIGHT, now)):
                    now = move(UP_RIGHT, now)
                else:
                    move_up = False
                    if inbounds(move(RIGHT, now)):
                        now = move(RIGHT, now)
                    else:
                        now = move(DOWN, now)
            else:
                if inbounds(move(DOWN_LEFT, now)):
                    now = move(DOWN_LEFT, now)
                else:
                    move_up = True
                    if inbounds(move(DOWN, now)):
                        now = move(DOWN, now)
                    else:
                        now = move(RIGHT, now)
        """
        for rows = cols = 8, the actual 1-D index:
            0, 1, 8, 16, 9, 2, 3, 10, 17, 24, 32, 25, 18, 11, 4, 5,
            12, 19, 26, 33, 40, 48, 41, 34, 27, 20, 13, 6, 7, 14, 21, 28,
            35, 42, 49, 56, 57, 50, 43, 36, 29, 22, 15, 23, 30, 37, 44, 51,
            58, 59, 52, 45, 38, 31, 39, 46, 53, 60, 61, 54, 47, 55, 62, 63
        """
        return trace


def RGB2YCbCr(im):
    im = im.astype(np.float32)
    im = cv2.cvtColor(im, cv2.COLOR_RGB2YCrCb)
    """
    RGB [0, 255]
    opencv uses the following equations to conduct color conversion in float32
        Y = 0.299 * R + 0.587 * G + 0.114 * B
        Cb = (B - Y) * 0.564 + 0.5
        Cr = (R - Y) * 0.713 + 0.5
    Y [0, 255], Cb, Cr [-128, 127]
```

```python
        """
        # convert YCrCb to YCbCr
        Y, Cr, Cb = np.split(im, 3, axis=-1)
        im = np.concatenate([Y, Cb, Cr], axis=-1)
        return im


def YCbCr2RGB(im):
    im = im.astype(np.float32)
    Y, Cb, Cr = np.split(im, 3, axis=-1)
    im = np.concatenate([Y, Cr, Cb], axis=-1)
    im = cv2.cvtColor(im, cv2.COLOR_YCrCb2RGB)
    """
    Y [0, 255], Cb, Cr [-128, 127]
    conversion equation (float32):
        B = (Cb - 0.5) / 0.564 + Y
        R = (Cr - 0.5) / 0.713 + Y
        G = (Y - 0.299 * R - 0.114 * B) / 0.587
    RGB [0, 255]
    """
    return im


def bits_required(n):
    n = abs(n)
    result = 0
    while n > 0:
        n >>= 1
        result += 1
    return result


def divide_blocks(im, mh, mw):
    h, w = im.shape[:2]
    return im.reshape(h // mh, mh, w // mw, mw).swapaxes(1, 2).reshape(-1, mh, mw)


def restore_image(block, nh, nw):
    bh, bw = block.shape[1:]
    return block.reshape(nh, nw, bh, bw).swapaxes(1, 2).reshape(nh * bh, nw * bw)


def flatten(lst):
    return [item for sublist in lst for item in sublist]


def averageMatrix(
    arrayMatrix,
):  # given an array of 2D-array, return the average (coef by coef) 2D array
    avgMatrix = np.zeros_like(arrayMatrix[0])
    for i in range(avgMatrix.shape[0]):
        for j in range(avgMatrix.shape[1]):
            avgMatrix[i, j] = np.average(arrayMatrix[:, i, j])
    return avgMatrix


if __name__ == "__main__":
    arrMatrix = np.array([[[1, 2], [3, 4]], [[5, 2], [3, 4]]])
```

```
429        print(averageMatrix(arrMatrix))
430
```

encoder/huffman_jpeg.py

```python
 1   import numpy as np
 2
 3   MAX_CLEN = 32   # assumed maximum initial code length
 4
 5
 6   def getFreq(data):
 7       freq = [0] * 257
 8       for elem in data:
 9           freq[elem] += 1
10       freq[256] = 1
11       return freq
12
13
14   def jpegGenerateOptimalTable(freq):
15       bits = [0] * (MAX_CLEN + 1)
16       bitPos = [0] * (MAX_CLEN + 1)
17       codesize = [0] * 257
18       nzIndex = [0] * 257
19
20       others = [-1] * 257
21
22       numNzSymbols = 0
23       for i in range(257):
24           if freq[i]:
25               nzIndex[numNzSymbols] = i
26               freq[numNzSymbols] = freq[i]
27               numNzSymbols += 1
28
29       huffval = [0] * (numNzSymbols - 1)
30
31       while True:
32           c1 = -1
33           c2 = -1
34           v = 1000000000
35           v2 = 1000000000
36           for i in range(numNzSymbols):
37               if freq[i] <= v2:
38                   if freq[i] <= v:
39                       c2 = c1
40                       v2 = v
41                       v = freq[i]
42                       c1 = i
43                   else:
44                       v2 = freq[i]
45                       c2 = i
46
47           if c2 < 0:
48               break
49
```

```
            freq[c1] += freq[c2]
            freq[c2] = 1000000001

            codesize[c1] += 1
            while others[c1] >= 0:
                c1 = others[c1]
                codesize[c1] += 1

            others[c1] = c2

            codesize[c2] += 1
            while others[c2] >= 0:
                c2 = others[c2]
                codesize[c2] += 1

    for i in range(numNzSymbols):
        bits[codesize[i]] += 1

    p = 0
    for i in range(1, MAX_CLEN + 1):
        bitPos[i] = p
        p += bits[i]

    for i in range(MAX_CLEN, 16, -1):
        while bits[i] > 0:
            j = i - 2
            while bits[j] == 0:
                j -= 1
            bits[i] -= 2
            bits[i - 1] += 1
            bits[j + 1] += 2
            bits[j] -= 1

    i = MAX_CLEN
    while bits[i] == 0:
        i -= 1
    bits[i] -= 1

    for i in range(numNzSymbols - 1):
        huffval[bitPos[codesize[i]]] = nzIndex[i]
        bitPos[codesize[i]] += 1

    return bits, huffval


def jpegGenerateHuffmanTable(bits, huffval):
    huffsize = [0] * 257
    huffcode = [0] * 257

    p = 0
    for l in range(1, 17):
        i = bits[l]
        while i:
            huffsize[p] = l
            p += 1
            i -= 1

    huffsize[p] = 0
```

```python
108          lastp = p
109
110          code = 0
111          si = huffsize[0]
112          p = 0
113          while huffsize[p]:
114              while huffsize[p] == si:
115                  huffcode[p] = code
116                  code += 1
117                  p += 1
118              code <<= 1
119              si += 1
120
121          ehufco = [0] * 257
122          ehufsi = [0] * 257
123
124          for p in range(lastp):
125              i = huffval[p]
126              ehufco[i] = huffcode[p]
127              ehufsi[i] = huffsize[p]
128
129          return ehufsi, ehufco
130
131
132  def jpegTransformTable(ehufsi, ehufco):
133      table = {}
134      for i in range(len(ehufco)):
135          if ehufsi[i] != 0:
136              endCode = bin(ehufco[i])[2:]
137              nbZeros = ehufsi[i] - len(endCode)
138              table[i] = "0" * nbZeros + endCode
139      return table
140
141
142  def jpegCreateHuffmanTable(arr):
143      freq = getFreq(arr)
144      bits, huffval = jpegGenerateOptimalTable(freq)
145      ehufsi, ehufco = jpegGenerateHuffmanTable(bits, huffval)
146      table = jpegTransformTable(ehufsi, ehufco)
147      return table
148
149
150  def convert_huffman_table(table):
151      """convert huffman table to count and weigh"""
152      # table[int] = string
153      pairs = sorted(table.items(), key=lambda x: (len(x[1]), x[1]))
154      weigh, codes = zip(*pairs)
155      weigh = np.array(weigh, dtype=np.uint8)
156      # count[i]: there are count[i] codes of length i+1
157      count = np.zeros(16, dtype=np.uint8)
158      for c in codes:
159          count[len(c) - 1] += 1
160      return count, weigh
161
162
163  def read_huffman_code(table, stream):
164      prefix = ""
165      while prefix not in table:
```

```python
            prefix += str(stream.read_bit())
        return table[prefix]


def reverse(table):
    return {v: k for k, v in table.items()}


# 4 recommended huffman tables in JPEG standard
# luminance DC
RM_Y_DC = {
    "00": 0,
    "010": 1,
    "011": 2,
    "100": 3,
    "101": 4,
    "110": 5,
    "1110": 6,
    "11110": 7,
    "111110": 8,
    "1111110": 9,
    "11111110": 10,
    "111111110": 11,
}

# luminance AC
RM_Y_AC = {
    "00": 1,
    "01": 2,
    "100": 3,
    "1010": 0,
    "1011": 4,
    "1100": 17,
    "11010": 5,
    "11011": 18,
    "11100": 33,
    "111010": 49,
    "111011": 65,
    "1111000": 6,
    "1111001": 19,
    "1111010": 81,
    "1111011": 97,
    "11111000": 7,
    "11111001": 34,
    "11111010": 113,
    "111110110": 20,
    "111110111": 50,
    "111111000": 129,
    "111111001": 145,
    "111111010": 161,
    "1111110110": 8,
    "1111110111": 35,
    "1111111000": 66,
    "1111111001": 177,
    "1111111010": 193,
    "11111110110": 21,
    "11111110111": 82,
    "11111111000": 209,
```

```json
    "11111111001": 240,
    "111111110100": 36,
    "111111110101": 51,
    "111111110110": 98,
    "111111110111": 114,
    "111111111000000": 130,
    "1111111110000010": 9,
    "1111111110000011": 10,
    "1111111110000100": 22,
    "1111111110000101": 23,
    "1111111110000110": 24,
    "1111111110000111": 25,
    "1111111110001000": 26,
    "1111111110001001": 37,
    "1111111110001010": 38,
    "1111111110001011": 39,
    "1111111110001100": 40,
    "1111111110001101": 41,
    "1111111110001110": 42,
    "1111111110001111": 52,
    "1111111110010000": 53,
    "1111111110010001": 54,
    "1111111110010010": 55,
    "1111111110010011": 56,
    "1111111110010100": 57,
    "1111111110010101": 58,
    "1111111110010110": 67,
    "1111111110010111": 68,
    "1111111110011000": 69,
    "1111111110011001": 70,
    "1111111110011010": 71,
    "1111111110011011": 72,
    "1111111110011100": 73,
    "1111111110011101": 74,
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    "1111111110011111": 84,
    "1111111110100000": 85,
    "1111111110100001": 86,
    "1111111110100010": 87,
    "1111111110100011": 88,
    "1111111110100100": 89,
    "1111111110100101": 90,
    "1111111110100110": 99,
    "1111111110100111": 100,
    "1111111110101000": 101,
    "1111111110101001": 102,
    "1111111110101010": 103,
    "1111111110101011": 104,
    "1111111110101100": 105,
    "1111111110101101": 106,
    "1111111110101110": 115,
    "1111111110101111": 116,
    "1111111110110000": 117,
    "1111111110110001": 118,
    "1111111110110010": 119,
    "1111111110110011": 120,
    "1111111110110100": 121,
    "1111111110110101": 122,
```

```
282        "1111111110110110": 131,
283        "1111111110110111": 132,
284        "1111111110111000": 133,
285        "1111111110111001": 134,
286        "1111111110111010": 135,
287        "1111111110111011": 136,
288        "1111111110111100": 137,
289        "1111111110111101": 138,
290        "1111111110111110": 146,
291        "1111111110111111": 147,
292        "1111111111000000": 148,
293        "1111111111000001": 149,
294        "1111111111000010": 150,
295        "1111111111000011": 151,
296        "1111111111000100": 152,
297        "1111111111000101": 153,
298        "1111111111000110": 154,
299        "1111111111000111": 162,
300        "1111111111001000": 163,
301        "1111111111001001": 164,
302        "1111111111001010": 165,
303        "1111111111001011": 166,
304        "1111111111001100": 167,
305        "1111111111001101": 168,
306        "1111111111001110": 169,
307        "1111111111001111": 170,
308        "1111111111010000": 178,
309        "1111111111010001": 179,
310        "1111111111010010": 180,
311        "1111111111010011": 181,
312        "1111111111010100": 182,
313        "1111111111010101": 183,
314        "1111111111010110": 184,
315        "1111111111010111": 185,
316        "1111111111011000": 186,
317        "1111111111011001": 194,
318        "1111111111011010": 195,
319        "1111111111011011": 196,
320        "1111111111011100": 197,
321        "1111111111011101": 198,
322        "1111111111011110": 199,
323        "1111111111011111": 200,
324        "1111111111100000": 201,
325        "1111111111100001": 202,
326        "1111111111100010": 210,
327        "1111111111100011": 211,
328        "1111111111100100": 212,
329        "1111111111100101": 213,
330        "1111111111100110": 214,
331        "1111111111100111": 215,
332        "1111111111101000": 216,
333        "1111111111101001": 217,
334        "1111111111101010": 218,
335        "1111111111101011": 225,
336        "1111111111101100": 226,
337        "1111111111101101": 227,
338        "1111111111101110": 228,
339        "1111111111101111": 229,
```

```python
        "1111111111110000": 230,
        "1111111111110001": 231,
        "1111111111110010": 232,
        "1111111111110011": 233,
        "1111111111110100": 234,
        "1111111111110101": 241,
        "1111111111110110": 242,
        "1111111111110111": 243,
        "1111111111111000": 244,
        "1111111111111001": 245,
        "1111111111111010": 246,
        "1111111111111011": 247,
        "1111111111111100": 248,
        "1111111111111101": 249,
        "1111111111111110": 250,
}

# chroma DC
RM_C_DC = {
    "00": 0,
    "01": 1,
    "10": 2,
    "110": 3,
    "1110": 4,
    "11110": 5,
    "111110": 6,
    "1111110": 7,
    "11111110": 8,
    "111111110": 9,
    "1111111110": 10,
    "11111111110": 11,
}

# chroma AC
RM_C_AC = {
    "00": 0,
    "01": 1,
    "100": 2,
    "1010": 3,
    "1011": 17,
    "11000": 4,
    "11001": 5,
    "11010": 33,
    "11011": 49,
    "111000": 6,
    "111001": 18,
    "111010": 65,
    "111011": 81,
    "1111000": 7,
    "1111001": 97,
    "1111010": 113,
    "11110110": 19,
    "11110111": 34,
    "11111000": 50,
    "11111001": 129,
    "111110100": 8,
    "111110101": 20,
    "111110110": 66,
```

```
    "111110111": 145,
    "111111000": 161,
    "111111001": 177,
    "111111010": 193,
    "1111110110": 9,
    "1111110111": 35,
    "1111111000": 51,
    "1111111001": 82,
    "1111111010": 240,
    "11111110110": 21,
    "11111110111": 98,
    "11111111000": 114,
    "11111111001": 209,
    "111111110100": 10,
    "111111110101": 22,
    "111111110110": 36,
    "111111110111": 52,
    "1111111100000": 225,
    "111111111000010": 37,
    "111111111000011": 241,
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    "1111111110011001": 69,
    "1111111110011010": 70,
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    "1111111110101000": 100,
    "1111111110101001": 101,
    "1111111110101010": 102,
    "1111111110101011": 103,
    "1111111110101100": 104,
    "1111111110101101": 105,
```

```
456        "1111111110101110": 106,
457        "1111111110101111": 115,
458        "1111111110110000": 116,
459        "1111111110110001": 117,
460        "1111111110110010": 118,
461        "1111111110110011": 119,
462        "1111111110110100": 120,
463        "1111111110110101": 121,
464        "1111111110110110": 122,
465        "1111111110110111": 130,
466        "1111111110111000": 131,
467        "1111111110111001": 132,
468        "1111111110111010": 133,
469        "1111111110111011": 134,
470        "1111111110111100": 135,
471        "1111111110111101": 136,
472        "1111111110111110": 137,
473        "1111111110111111": 138,
474        "1111111111000000": 146,
475        "1111111111000001": 147,
476        "1111111111000010": 148,
477        "1111111111000011": 149,
478        "1111111111000100": 150,
479        "1111111111000101": 151,
480        "1111111111000110": 152,
481        "1111111111000111": 153,
482        "1111111111001000": 154,
483        "1111111111001001": 162,
484        "1111111111001010": 163,
485        "1111111111001011": 164,
486        "1111111111001100": 165,
487        "1111111111001101": 166,
488        "1111111111001110": 167,
489        "1111111111001111": 168,
490        "1111111111010000": 169,
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496        "1111111111010110": 182,
497        "1111111111010111": 183,
498        "1111111111011000": 184,
499        "1111111111011001": 185,
500        "1111111111011010": 186,
501        "1111111111011011": 194,
502        "1111111111011100": 195,
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505        "1111111111011111": 198,
506        "1111111111100000": 199,
507        "1111111111100001": 200,
508        "1111111111100010": 201,
509        "1111111111100011": 202,
510        "1111111111100100": 210,
511        "1111111111100101": 211,
512        "1111111111100110": 212,
513        "1111111111100111": 213,
```

```
514         "1111111111101000": 214,
515         "1111111111101001": 215,
516         "1111111111101010": 216,
517         "1111111111101011": 217,
518         "1111111111101100": 218,
519         "1111111111101101": 226,
520         "1111111111101110": 227,
521         "1111111111101111": 228,
522         "1111111111110000": 229,
523         "1111111111110001": 230,
524         "1111111111110010": 231,
525         "1111111111110011": 232,
526         "1111111111110100": 233,
527         "1111111111110101": 234,
528         "1111111111110110": 242,
529         "1111111111110111": 243,
530         "1111111111111000": 244,
531         "1111111111111001": 245,
532         "1111111111111010": 246,
533         "1111111111111011": 247,
534         "1111111111111100": 248,
535         "1111111111111101": 249,
536         "1111111111111110": 250,
537 }
538
539 if __name__ == "__main__":
540     arr = np.array([np.random.randint(-127, 128) for _ in range(64)])
541     table = jpegCreateHuffmanTable(arr)
542     print(table)
543
```

encoder/encoder.py

```python
 1  from math import ceil
 2  import cv2
 3  import numpy as np
 4  from PIL import Image
 5  from pathlib import Path
 6
 7  from utils import *
 8  from huffman_jpeg import *
 9
10
11  def padding(im, mh, mw):
12      """
13      pad use boundary pixels so that its height and width are
14      the multiple of the height and width of MCUs, respectively
15      """
16      h, w, d = im.shape
17      if h % mh == 0 and w % mw == 0:
18          return im
19      hh, ww = ceil(h / mh) * mh, ceil(w / mw) * mw
20      im_ex = np.zeros_like(im, shape=(hh, ww, d))
21      im_ex[:h, :w] = im
```

```python
            im_ex[:, w:] = im_ex[:, w - 1 : w]
            im_ex[h:, :] = im_ex[h - 1 : h, :]
        return im_ex


mcu_sizes = {
    "4:2:0": (BH * 2, BW * 2),
    "4:1:1": (BH * 2, BW * 2),
    "4:2:2": (BH, BW * 2),
    "4:4:4": (BH, BW),
}


def scan_blocks(mcu, mh, mw):
    """
    scan MCU to blocks for DPCM, for 4:2:0, the scan order is as follows:
    --------- | ---------
    | 0 | 1 | | | 4 | 5 |
    --------- | ---------
    | 2 | 3 | | | 6 | 7 |
    --------- | ---------
    """
    blocks = (
        mcu.reshape(-1, mh // BH, BH, mw // BW, BW).swapaxes(2, 3).reshape(-1, BH,
    BW)
    )
    return blocks


def DCT(blocks):
    dct = np.zeros_like(blocks)
    for i in range(blocks.shape[0]):
        dct[i] = cv2.dct(blocks[i])
    return dct


def zigzag_encode(dct):
    trace = zigzag_points(BH, BW)
    zz = np.zeros_like(dct).reshape(-1, BH * BW)
    for i, p in enumerate(trace):
        zz[:, i] = dct[:, p[0], p[1]]
    return zz


def quantization(dct, table):
    ret = dct / table[None]
    return np.round(ret).astype(np.int32)


def DPCM(dct):
    """
    encode the DC differences
    """
    dc_pred = dct.copy()
    dc_pred[1:, 0] = dct[1:, 0] - dct[:-1, 0]
    return dc_pred


def run_length_encode(arr):
```

```python
 80            # determine where the sequence is ending prematurely
 81            last_nonzero = -1
 82            for i, elem in enumerate(arr):
 83                if elem != 0:
 84                    last_nonzero = i
 85            rss, values = [], []
 86            run_length = 0
 87            for i, elem in enumerate(arr):
 88                if i > last_nonzero:
 89                    rss.append(0)
 90                    values.append(0)
 91                    break
 92                elif elem == 0 and run_length < 15:
 93                    run_length += 1
 94                else:
 95                    size = bits_required(elem)
 96                    rss.append((run_length << 4) + size)
 97                    values.append(elem)
 98                    run_length = 0
 99            return rss, values


102    def encode_header(qts, hts, cop_infos, height, width):
103        writer = BytesWriter()
104        add_bytes = writer.add_bytes
105        add_bytes(
106            MARKER.SOI,
107            MARKER.APP0,
108            b"\x00\x10",  # length = 16
109            b"JFIF\x00",  # identifier = JFIF0
110            b"\x01\x01",  # version
111            b"\x00",  # unit
112            b"\x00\x01",  # x density
113            b"\x00\x01",  # y density
114            b"\x00\x00",  # thumbnail data
115        )
116        for id_, qt in enumerate(qts):
117            add_bytes(
118                MARKER.DQT,
119                b"\x00C",  # length = 67
120                # precision (8 bits), table id, = 0, id_
121                int2bytes(id_, 1),
122                qt.astype(np.uint8).tobytes(),
123            )
124        cop_num = len(cop_infos)
125        add_bytes(
126            MARKER.SOF0,
127            int2bytes(8 + 3 * cop_num, 2),  # length
128            int2bytes(8, 1),  # 8 bit precision
129            int2bytes(height, 2),
130            int2bytes(width, 2),
131            int2bytes(cop_num, 1),
132        )
133        add_bytes(*[info.encode_SOF0_info() for info in cop_infos])
134
135        # type << 4 + id, (type 0: DC, 1 : AC)
136        type_ids = [b"\x00", b"\x10", b"\x01", b"\x11"]
137        for type_id, ht in zip(type_ids, hts):
```

```python
            count, weigh = convert_huffman_table(ht)
            ht_bytes = count.tobytes() + weigh.tobytes()
            add_bytes(
                MARKER.DHT,
                int2bytes(len(ht_bytes) + 3, 2),  # length
                type_id,
                ht_bytes,
            )

    add_bytes(
        MARKER.SOS,
        int2bytes(6 + cop_num * 2, 2),  # length
        int2bytes(cop_num, 1),
    )
    add_bytes(*[info.encode_SOS_info() for info in cop_infos])
    add_bytes(b"\x00\x3f\x00")
    return writer


def encode_mcu(mcu, hts):
    bit_stream = BitStreamWriter()
    for cur in mcu:
        for dct, (dc_ht, ac_ht) in zip(cur, hts):
            dc_code = encode_2s_complement(dct[0])
            container = [dc_ht[len(dc_code)], dc_code]
            rss, values = run_length_encode(dct[1:])
            for rs, v in zip(rss, values):
                container.append(ac_ht[rs])
                container.append(encode_2s_complement(v))
            bitstring = "".join(container)
            bit_stream.write_bitstring(bitstring)
    return bit_stream.to_bytes()


def encode_jpeg(im, quality=95, subsample="4:2:0", use_rm_ht=True):
    im = np.expand_dims(im, axis=-1) if im.ndim == 2 else im
    height, width, depth = im.shape

    mh, mw = mcu_sizes[subsample] if depth == 3 else (BH, BW)
    im = padding(im, mh, mw)
    im = RGB2YCbCr(im) if depth == 3 else im

    # DC level shift for luminance,
    # the shift of chroma was completed by color conversion
    Y_im = im[:, :, 0] - 128
    # divide image into MCUs
    mcu = divide_blocks(Y_im, mh, mw)
    # MCU to blocks, for luminance there are more than one blocks in each MCU
    Y = scan_blocks(mcu, mh, mw)
    Y_dct = DCT(Y)
    # the quantization table was already processed by zigzag scan,
    # so we apply zigzag encoding to DCT block first
    Y_z = zigzag_encode(Y_dct)
    qt_y = load_quantization_table(quality, "lum")
    Y_q = quantization(Y_z, qt_y)
    Y_p = DPCM(Y_q)
    # whether to use recommended huffman table
    if use_rm_ht:
```

```python
            Y_dc_ht, Y_ac_ht = reverse(RM_Y_DC), reverse(RM_Y_AC)
        else:
            Y_dc_ht = jpegCreateHuffmanTable(np.vectorize(bits_required)(Y_p[:, 0]))
            Y_ac_ht = jpegCreateHuffmanTable(
                flatten(run_length_encode(Y_p[i, 1:])[0] for i in range(Y_p.shape[0]))
            )
        qts, hts = [qt_y], [Y_dc_ht, Y_ac_ht]
        cop_infos = [ComponentInfo(1, mw // BW, mh // BH, 0, 0, 0)]
        # the number of Y DCT blocks in an MCU
        num = (mw // BW) * (mh // BH)
        mcu_hts = [(Y_dc_ht, Y_ac_ht) for _ in range(num)]
        # assign DCT blocks to MCUs
        mcu_ = Y_p.reshape(-1, num, BH * BW)

        if depth == 3:
            # chroma subsample
            ch = im[:: mh // BH, :: mw // BW, 1:]
            Cb = divide_blocks(ch[:, :, 0], BH, BW)
            Cr = divide_blocks(ch[:, :, 1], BH, BW)
            Cb_dct, Cr_dct = DCT(Cb), DCT(Cr)
            Cb_z, Cr_z = zigzag_encode(Cb_dct), zigzag_encode(Cr_dct)
            qt_c = load_quantization_table(quality, "chr")
            Cb_q, Cr_q = quantization(Cb_z, qt_c), quantization(Cr_z, qt_c)
            Cb_p, Cr_p = DPCM(Cb_q), DPCM(Cr_q)
            if use_rm_ht:
                C_dc_ht, C_ac_ht = reverse(RM_C_DC), reverse(RM_C_AC)
            else:
                ch_ = np.concatenate([Cb_p, Cr_p], axis=0)
                C_dc_ht = jpegCreateHuffmanTable(np.vectorize(bits_required)(ch_[:,
    0]))
                C_ac_ht = jpegCreateHuffmanTable(
                    flatten(run_length_encode(ch_[i, 1:])[0] for i in
    range(ch_.shape[0]))
                )
            qts.append(qt_c), hts.extend([C_dc_ht, C_ac_ht])
            cop_infos.extend(
                [ComponentInfo(2, 1, 1, 1, 1, 1), ComponentInfo(3, 1, 1, 1, 1, 1)]
            )
            mcu_hts.extend((C_dc_ht, C_ac_ht) for _ in range(2))
            mcu_ = np.concatenate([mcu_, Cb_p[:, None], Cr_p[:, None]], axis=1)

    writer = encode_header(qts, hts, cop_infos, height, width)
    bytes_ = encode_mcu(mcu_, mcu_hts)
    writer.write(bytes_.replace(b"\xff", b"\xff\x00"))
    writer.write(MARKER.EOI)
    return writer.getvalue()


def write_jpeg(filename, im, quality=95, subsample="4:2:0", use_rm_ht=True):
    bytes_ = encode_jpeg(im, quality, subsample, use_rm_ht)
    Path(filename).write_bytes(bytes_)


def main():
    im = Image.open("./data/villeLyon.jpg")
    write_jpeg("data/villeLyonLow.jpg", np.array(im), 5, "4:1:1", False)


if __name__ == "__main__":
```

```
253     main()
254
```

encoder/comparator.py

```python
 1  import numpy as np
 2  import encoder
 3  import sys, os
 4  from pathlib import Path
 5  from PIL import Image
 6  import cv2
 7  import pandas as pd
 8  import time as t
 9  import shutil
10  import utils
11  import matplotlib.pyplot as plt
12  from encoder import DCT, padding
13  from scipy.fftpack import dct
14  import random as rd
15
16  LIM = 2  # number of files to test to
17
18
19  def compare(
20      qualities=None,
21      dataDirectory=None,
22      outputDirectory=None,
23      subsamples=None,
24      useStdHuffmanTable=None,
25      DeleteFilesAfterward=True,
26  ):
27      if qualities is None:
28          qualities = [np.random.randint(0, 101)]
29      if subsamples is None:
30          subsamples = ["4:2:2"]
31      if dataDirectory is None:
32          dataDirectory = "./data/datasetBmp"
33      if useStdHuffmanTable is None:
34          useStdHuffmanTable = [False]
35      stat = np.zeros(
36          (LIM * len(qualities) * len(subsamples) * len(useStdHuffmanTable), 6),
37          dtype=object,
38      )  # dim 0 : quality factor, dim 1 : subsample method, dim 2 : usage of std Hf
    Tables, dim 3 : size before compression, dim 4 : size after compression, dim 5 :
    time to compress
39      i = 0
40      i_max = LIM * len(qualities) * len(subsamples) * len(useStdHuffmanTable)
41      filesTreated = rd.choices(os.listdir(dataDirectory), k=LIM)
42      for quality in qualities:
43          for subsample in subsamples:
44              for hfTables in useStdHuffmanTable:
45                  outputDirectory = f"./data/treated/quality{quality}-
    subsample{subsample}-stdHf{hfTables}"
46                  for filename in filesTreated:
47                      f = os.path.join(dataDirectory, filename)
```

```python
                              if not os.path.exists(outputDirectory):
                                  os.makedirs(outputDirectory)
                          f_out = os.path.join(outputDirectory, filename + ".jpg")
                          if os.path.isfile(f):
                              previousSize = os.stat(f).st_size
                              image = Image.open(f)
                              time = t.time()
                              encoder.write_jpeg(
                                  f_out, np.array(image), quality, subsample, hfTables
                              )
                              time = t.time() - time
                              newSize = os.stat(f_out).st_size
                              stat[i][0] = quality
                              stat[i][1] = subsample
                              stat[i][2] = hfTables
                              stat[i][3] = previousSize
                              stat[i][4] = newSize
                              stat[i][5] = time
                          i += 1
                          print(f"{i}/{i_max}", end="\r")
                  if DeleteFilesAfterward:
                      shutil.rmtree(outputDirectory)
    return stat


def write_stat(statFile, stat, quality, subsample, standHuffTables):
    with open(statFile, "a+") as f:
        f.write("\n" * 2)
        f.write("New sample \n")
        f.write(f"Size of sample : {LIM} images \n")
        f.write(
            f"Parameters of compression : (quality) {quality}, (subsample)
{subsample}, (usage of standard HuffTables) {'Yes' if standHuffTables else 'No'}
\n"
        )
        avgPreviousSize = np.average(stat[:, 0])
        avgNewSize = np.average(stat[:, 1])
        f.write(
            f"Average size of image before compression : {avgPreviousSize} bytes
\n"
        )
        f.write(f"Average size of images after compression : {avgNewSize} bytes
\n")
        f.write(f"Ratio is {avgPreviousSize / avgNewSize:.2f}")


def write_stat_csv(output, stat):
    if os.path.isfile(output):
        pd.DataFrame(stat).to_csv(output, mode="a", index=False, header=False)
    else:
        pd.DataFrame(stat).to_csv(
            output,
            index=False,
            header=[
                "quality",
                "subsample",
                "stdHuffmanTables",
                "oldSize",
                "newSize",
```

```python
                    "time",
                ],
            )


def csv_to_stat(csvFile):
    stat = pd.read_csv(csvFile)
    return stat


def dataInterpreation(dataFrame):
    df = dataFrame
    qualities = df["quality"].unique()
    qualitySize = {}
    qualityTime = {}
    for quality in qualities:
        qualitySize[quality] = int(df[df["quality"] == quality]["newSize"].mean())
        qualityTime[quality] = round(df[df["quality"] == quality]["time"].mean(),
3)
    stdSize = int(df[df["stdHuffmanTables"] == True]["newSize"].mean())
    stdTime = round(df[df["stdHuffmanTables"] == True]["time"].mean(), 3)
    nonStdSize = int(df[df["stdHuffmanTables"] == False]["newSize"].mean())
    nonStdTime = round(df[df["stdHuffmanTables"] == False]["time"].mean(), 3)

    plt.rcParams["figure.figsize"] = [10, 5]

    fig, (ax1, ax3) = plt.subplots(1, 2)
    ax2 = ax1.twinx()

    fig.suptitle("Comparaison des compressions en fonction du facteur de qualité")

    width = 0.25

    initialSize = 786486
    xaxis = list(qualitySize.keys())
    yaxisSize = np.array(list(qualitySize.values()))
    yaxisTime = np.array(list(qualityTime.values()))
    yaxisRatio = (initialSize - yaxisSize) / yaxisTime

    color1 = "tab:red"
    color2 = "tab:blue"
    color3 = "tab:green"

    ax1.bar(
        np.arange(len(qualitySize)) - width,
        yaxisSize,
        width,
        tick_label=xaxis,
        color=color1,
        label="Taille après compression",
    )
    ax2.bar(
        np.arange(len(qualityTime)),
        yaxisTime,
        width,
        tick_label=xaxis,
        color=color2,
        label="Temps de compression",
    )
```

```python
        ax3.bar(
            np.arange(len(qualitySize)),
            yaxisRatio,
            width,
            tick_label=xaxis,
            color=color3,
            label="Octets gagnés par seconde",
        )

        ax1.legend(loc="upper left")
        ax2.legend(loc="upper left", bbox_to_anchor=(0, 0.9))
        ax3.legend(loc="upper right")

        ax3.yaxis.tick_right()

        ax1.set_xlabel("Facteur de qualité")
        ax1.set_ylabel("Taille (en octets)", color=color1)
        ax2.set_ylabel("Temps (en secondes)", color=color2)
        ax3.set_xlabel("Facteur de qualité")
        ax3.set_ylabel("Taille gagné par unité de temps (octets.Hz)", color=color3)
        ax3.yaxis.set_label_position("right")

        plt.savefig("./data/treated/compressionComparaison", transparent=True)

        plt.rcParams["figure.figsize"] = [7, 5]
        plt.clf()

        fig = plt.figure()
        ax1 = fig.add_subplot(111)
        ax2 = ax1.twinx()

        fig.suptitle(
            "Comparaison des compressions en fonction des tables de Huffman utilisées"
        )

        yaxisSize = [stdSize, nonStdSize]
        yaxisTime = [stdTime, nonStdTime]

        labels = ["Tables Standards", "Tables Optimales"]
        ax1.bar(
            np.arange(2) - width / 2,
            yaxisSize,
            width,
            tick_label=labels,
            color=color1,
            label="Taille après compression",
        )
        ax2.bar(
            np.arange(2) + width / 2,
            yaxisTime,
            width,
            tick_label=labels,
            color=color2,
            label="Temps de compression",
        )

        ax1.legend(loc="upper center", bbox_to_anchor=(0.45, 1))
        ax2.legend(loc="upper center", bbox_to_anchor=(0.45, 0.9))
```

```python
219
220         ax1.set_ylabel("Taille (en octets)", color=color1)
221         ax2.set_ylabel("Temps (en secondes)", color=color2)
222
223         plt.savefig("./data/treated/compressionComparaison2", transparent=True)
224
225
226     def energyCompaction(imgPath):
227         img = cv2.imread(imgPath)
228
229         imgYCrCB = cv2.cvtColor(
230             img, cv2.COLOR_RGB2YCrCb
231         )  # Convert RGB to YCrCb (Cb applies V, and Cr applies U).
232
233         Y, Cr, Cb = cv2.split(padding(imgYCrCB, 8, 8))
234         Y = Y.astype("int") - 128
235         blocks_Y = utils.divide_blocks(Y, 8, 8)
236         dctBlocks_Y = np.zeros_like(blocks_Y)
237         for i in range(len(blocks_Y)):
238             dctBlocks_Y[i] = dct(
239                 dct(blocks_Y[i], axis=0, norm="ortho"), axis=1, norm="ortho"
240             )
241         avg_Y = utils.averageMatrix(blocks_Y)
242         avgDct_Y = utils.averageMatrix(dctBlocks_Y)
243
244         x = np.random.randint(blocks_Y.shape[0])
245         arr1 = blocks_Y[x]
246         arr2 = dctBlocks_Y[x]
247
248         fig, (ax1, ax2) = plt.subplots(1, 2)
249
250         valueMax, valueMin = max(np.max(arr1), np.max(arr2)), min(
251             np.min(arr1), np.min(arr2)
252         )
253         # fig.suptitle('Matrice de la luminance de "villeLyon.jpg"')
254
255         ax1.matshow(arr1, cmap="cool", vmin=valueMin, vmax=valueMax)
256         ax1.set_title("avant DCT")
257
258         ax2.matshow(arr2, cmap="cool", vmin=valueMin, vmax=valueMax)
259         ax2.set_title("après DCT")
260
261         for i in range(arr1.shape[0]):
262             for j in range(arr1.shape[1]):
263                 cNormal = int(arr1[i, j])
264                 cDct = int(arr2[i, j])
265                 ax1.text(i, j, str(cNormal), va="center", ha="center")
266                 ax2.text(i, j, str(cDct), va="center", ha="center")
267         plt.savefig("./data/energyCompaction.png", transparent=True)
268
269
270     def rgbToYCbCr_channel_bis():
271         img = cv2.imread("./data/villeLyon.jpg")  # Read input image in BGR format
272
273         imgYCrCB = cv2.cvtColor(
274             img, cv2.COLOR_BGR2YCrCb
275         )  # Convert RGB to YCrCb (Cb applies V, and Cr applies U).
276
```

```python
    Y, Cr, Cb = cv2.split(imgYCrCB)

    # Fill Y and Cb with 128 (Y level is middle gray, and Cb is "neutralized").
    onlyCr = imgYCrCB.copy()
    onlyCr[:, :, 0] = 128
    onlyCr[:, :, 2] = 128
    onlyCr_as_bgr = cv2.cvtColor(
        onlyCr, cv2.COLOR_YCrCb2BGR
    )  # Convert to BGR - used for display as false color

    # Fill Y and Cr with 128 (Y level is middle gray, and Cr is "neutralized").
    onlyCb = imgYCrCB.copy()
    onlyCb[:, :, 0] = 128
    onlyCb[:, :, 1] = 128
    onlyCb_as_bgr = cv2.cvtColor(
        onlyCb, cv2.COLOR_YCrCb2BGR
    )  # Convert to BGR - used for display as false color

    cv2.imshow("img", img)
    cv2.imshow("Y", Y)
    cv2.imshow("onlyCb_as_bgr", onlyCb_as_bgr)
    cv2.imshow("onlyCr_as_bgr", onlyCr_as_bgr)
    cv2.waitKey()
    cv2.destroyAllWindows()

    cv2.imwrite("./data/treated/villeLyon_Y.jpg", Y)
    cv2.imwrite("./data/treated/villeLyon_Cb.jpg", onlyCb_as_bgr)
    cv2.imwrite("./data/treated/villeLyon_Cr.jpg", onlyCr_as_bgr)


if __name__ == "__main__":
    # compare()
    # rgbToYCbCr_channel_bis()
    # energyCompaction("./data/villeLyon.jpg")
    # test = np.array([[93, 90, 83, 68, 61, 61, 46, 21],
    #                  [102, 92, 95, 77, 65, 60, 49, 32],
    #                  [69, 55, 47, 57, 65, 60, 72, 65],
    #                  [55, 55, 40, 42, 23, 1, 11, 38],
    #                  [55, 57, 47, 53, 35, 59, -2, 26],
    #                  [64, 41, 42, 55, 60, 57, 25, -8],
    #                  [77, 87, 58, -2, -5, 14, -10, -35],
    #                  [38, 14, 33, 33, -21, -23, -43, -34]])
    # print(dct(dct(test, axis=0, norm="ortho"), axis=1, norm='ortho'))

    # stat = compare(qualities = list(range(1, 101, 10)), subsamples=['4:4:4',
    '4:2:0', '4:1:1', '4:2:2'], useStdHuffmanTable=[True, False],
    DeleteFilesAfterward=True)
    # write_stat_csv("./data/treated/stat.csv", stat)
    stat = csv_to_stat("./data/treated/stat.csv")
    dataInterpreation(stat)
```