Huffman's algorithm

```
import heapq
from pprint import pprint

DICTIONARY = dict[str, str]

class Huffman:
    """ Huffman algorithm """
    def encode(self, message: str) -> str:
        """encode by Huffman algorithm

        Args:
            message (str): message to encode

        Returns:
            str: encoded message

        >>> huffman = Huffman()
        >>> huffman.encode('Lorem ipsum dolor sit.')

'1111110100011101011100010110110011100101110011100101110101010001000010101100011110'
        """
        dictionary = self.get_dictionary(message)

        # get code for every character in message
        result = "".join([dictionary[element] for element in message])
        return result

    def get_dictionary(self, message: str) -> DICTIONARY:
        """dictionary of Huffman code

        Args:
            message (str): message to encode

        Returns:
            DICTIONARY: dictionary that was used to encode

        >>> huffman = Huffman()
        >>> huffman.get_dictionary('abacabacacabaca')
        {'b': '00', 'a': '1', 'c': '01'}
        """
        unique = set(message)
        probabilities = []

        for letter in unique:
            heapq.heappush(probabilities, [message.count(letter), 0,
letter])
```

```
        # get encoding scheme and convert it to dictionary
        scheme = self.__create_scheme(probabilities)
        dictionary = {element[2]: element[1] for element in scheme}

        return dictionary

    def __create_scheme(self, probabilities):
        """
        encoding scheme
        It has to be a tree, but I decided to work with lists
        """
        # if only 1 element in string
        if len(probabilities) <= 1:
            return [[probabilities[0][0], str(probabilities[0][1]),
probabilities[0][2]]]

        # if we divided it to 2 symbols
        if len(probabilities) == 2:
            first, second = probabilities
            first[1] = '0'
            second[1] = '1'
            return [first, second]

        # three and more letters
        # get 2 elements with lowest probabilities and sum them
        first_lowest = heapq.heappop(probabilities)
        second_lowest = heapq.heappop(probabilities)

        lowest_sum = first_lowest[0] + second_lowest[0]

        heapq.heappush(probabilities, [lowest_sum, 0])

        # recursively add 2 elements with lowest probabilities
        probabilities = self.__create_scheme(probabilities)

        # code for this 2-elements
        code = None
        for idx, element in enumerate(probabilities):
            # find 2-elements and delete it from heapq
            # if len(element) == 3 => that's not 2-elements, it's a
character
            # with the same probability
            if element[0] == lowest_sum and len(element) < 3:
                code = element[1]
                del probabilities[idx]
                break

        # add 0 and 1 to left and right element
```

```
            first_lowest[1] = code + '0'
            second_lowest[1] = code + '1'

            heapq.heappush(probabilities, first_lowest)
            heapq.heappush(probabilities, second_lowest)

            return probabilities

        def decode(self, message: str, dictionary: DICTIONARY) -> str:
            """Decode message by Huffman algorithm

            Args:
                message (str): encoded message
                dictionary (DICTIONARY): dictionary that was created while
encoding

            Returns:
                str: decoded message

            >>> huffman = Huffman()
            >>> huffman.decode('100101100101101100101011', {'b': '00', 'a':
'1', 'c': '01'})
            'abacabacacabaca'
            """
            reverse_dictionary = {value: key for key, value in
dictionary.items()}

            result = ""

            idx = 0

            # find a code that's in dictionary and decode it
            while idx < len(message):
                for length in range(1, len(message) + 1):
                    code = message[idx : idx + length]

                    if code in reverse_dictionary:
                        result += reverse_dictionary[code]
                        idx += length
                        break

            return result

        def assertion(self, message: str, verbose = False):
            """Test a string. Prints encoded message, dictionary and
            checks weather message == decode(encode(message)).
            In case it's not — returns error.

            Args:
```

```
            message (str): test message
            verbose (bool, optional): Show full info. Defaults to
False.

        >>> huffman = Huffman()
        >>> huffman.assertion('abaca')
        """
        encoded = self.encode(message)
        dictionary = self.get_dictionary(message)

        if verbose:
            print(f"Encoded: {encoded}")
            pprint(dictionary)

        assert message == self.decode(encoded, dictionary)
```

LZW algorithm

```
class LZW:
    """ LZW class """
    def compress(self, message: str) -> list[int]:
        """Compress message

        Args:
            message (str): message to compress

        Returns:
            list[int]: compressed message (list of ints)

        >>> lzw = LZW()
        >>> lzw.compress('abacabadabacacacd')
        [0, 1, 0, 2, 4, 0, 3, 8, 7, 12, 3]
        """
        # get only unique strings of length 1
        dictionary = self.get_initial_dictionary(message)
        code = []

        idx = 0
        message_length = len(message)

        # go through every letter
        while idx < message_length:
            # get str of every length
            for length in range(1, message_length + 1):
                current = message[idx : idx + length]

                # if this substr is in dictionary skip this
                if current in dictionary and (idx + length <=
message_length):
                    continue
```

```
                # get previous substr (without last letter)
                length -= 1
                prev = message[idx : idx + length]

                code.append(dictionary.index(prev))
                dictionary.append(current)

                idx += length
                break

        return code

    @staticmethod
    def get_initial_dictionary(message: str) -> list[str]:
        """get only unique strings of length 1.

        Args:
            message (str): initial message

        Returns:
            list[str]: dictionary

        >>> lzw = LZW()
        >>> lzw.get_initial_dictionary('abacabadabacacacd')
        ['a', 'b', 'c', 'd']
        """
        return list(sorted(set(message)))

    @staticmethod
    def decompress(code: str, dictionary: list[str]) -> str:
        """decompress compressed message

        Args:
            code (str): code which represents message
            dictionary (list[str]): initial dictionary of message

        Returns:
            str: decoded message

        >>> lzw = LZW()
        >>> lzw.decompress([0, 1, 0, 2, 4, 0, 3, 8, 7, 12, 3], ['a',
'b', 'c', 'd'])
        'abacabadabacacacd'
        """
        message = ""

        for idx, element in enumerate(code):
            decoded = dictionary[element]
```

```
            message += decoded

            # if not out of range
            if idx + 1 >= len(code):
                break

            # if next code is in dictionary
            if code[idx + 1] < len(dictionary):
                # add to dict this decoded element + first letter of
next
                dictionary.append(decoded + dictionary[code[idx + 1]]
[0])
            else:
                # add only this decoded and first letter of current
                dictionary.append(decoded + decoded[0])

        return message

    def assertion(self, message: str, verbose = False):
        """Checks weather message == decompress(compress(message))

        Args:
            message (str): original message
            verbose (bool, optional): full info. Defaults to True.

        >>> lzw = LZW()
        >>> lzw.assertion('abacabadabacacacd')
        """
        compressed = self.compress(message)
        dictionary = self.get_initial_dictionary(message)

        if verbose:
            print(f"Compressed: {compressed}")
            print(f"Minimal dictionary: {dictionary}")

        assert message == self.decompress(compressed, dictionary)
```

LZ77 algorithm

```
from math import ceil
from os import path


class LZ77:
    """
    Lempel-Ziv algorithm.
    """
    @staticmethod
    def compress(message: str, buffer_size: int = 8192) ->
list[tuple]:
```

```
        """
        Compressing message with lz77 algorithm.

        Args:
            message (str): message to compress
            buffer_size (int): size of the buffer (default 5)

        Returns:
            list[tuple[int, int, str]]: compressed message
            (list of tuples with three elements: <offset, length,
next>)

        >>> lz77 = LZ77()
        >>> lz77.compress('abacabacabadaca', 5)
        [(0, 0, 'a'), (0, 0, 'b'), (2, 1, 'c'), (4, 7, 'd'), (2, 1,
'c'), (2, 1, None)]
        """
        if not all([isinstance(message, str), isinstance(buffer_size,
int)]):
            return None

        result = []
        buffer = ''
        ind = 0

        while ind < len(message):
            start = ind
            copy_buff = buffer

            while message[start : ind + 1] in buffer and ind !=
len(message):
                ind += 1

                if message[start : ind + 1] not in buffer:
                    buffer *= 2

            ext_buff = buffer
            buffer = copy_buff
            i = ind + 1

            # finding offset
            substr = message[start : i]
            copy_substr = substr[:-1]

            while substr not in buffer:
                i -= 1
                substr = message[start : i]

            offset = 0 if len(substr) == 0 else buffer.rfind(substr)
```

```
            if len(substr) != 0:
                offset = len(buffer) - offset

            if offset != 0:
                while copy_substr != ext_buff[
                    len(buffer) - offset : len(buffer) - offset +
len(copy_substr)]:
                    offset -= 1

            # getting the next symbol
            if len(message[start : ind + 1]) == ind - start:
                next_sym = None
            else:
                next_sym = message[start : ind + 1][-1]

            # forming tuples
            result.append((offset, len(message[start : ind]),
next_sym))

            # updating buffer
            buffer += message[start : ind + 1]
            buffer = buffer[-buffer_size:] if len(buffer) >
buffer_size else buffer
            ind += 1

        return result


    @staticmethod
    def decompress(encoded_message: list[tuple], buffer_size: int =
8192) -> str:
        """
        Decompressing encoded message.

        Args:
            encoded_message (list[tuple]): encoded message

        Returns:
            str: decoded string

        >>> lz77 = LZ77()
        >>> lz77.decompress([(0, 0, 'a'), (0, 0, 'b'), (2, 1, 'c'), \
(4, 7, 'd'), (2, 1, 'c'), (2, 1, None)])
        'abacabacabadaca'
        """
        if not isinstance(encoded_message, list) or not
isinstance(buffer_size, int):
            return None
```

```
        if not all(len(i) == 3 and isinstance(i, tuple) for i in
encoded_message):
            return None

        if not all(isinstance(i, int) and isinstance(j, int) and
                   (z is None or isinstance(z, str)) for i, j, z in
encoded_message):
            return None

        result = ''

        for offset, length, next_sym in encoded_message:
            buffer = result[-buffer_size:]
            start = len(buffer) - offset
            stop = start + length
            next_sym = '' if next_sym is None else next_sym

            if offset < length:
                result += (buffer * ceil(length / offset))[start :
stop] + next_sym
            else:
                result += buffer[start : stop] + next_sym

        return result


    @classmethod
    def read_compress_file(cls, file_path: str):
        """
        Read content from file.

        Args:
            path (str): path to the existing file

        Returns:
            list[tuple[int, int, str]]: compressed message
            (list of tuples with three elements: <offset, lenght,
next>)
        """
        if not isinstance(file_path, str) or not
path.exists(file_path):
            return None

        if not path.isfile(file_path):
            print(f"There is not such file {file_path}")
            return None

        with open(file_path, 'r', encoding='utf-8') as file:
```

```
            content = file.read()

        name = file_path.split('/')[-1].split('.')[0] + '_encoded'

        with open(f'{name}.txt', 'w', encoding='utf-8') as fil:
            result = []

            for offset, length, next_character in
cls.compress(content):
                result.append(f"{offset}{length}{next_character or '
'}")

            fil.write("".join(result))

        return None

    @classmethod
    def assertion(cls, message: str) -> bool:
        """
        Assert an initial message is equal to the encoded an decoded
one.

        Args:
            message (str): message to check the correctness

        Returns:
            bool: True if they are equal, False otherwise.

        >>> lz77 = LZ77()
        >>> lz77.assertion('abacabacabadaca')
        >>>
lz77.assertion('1100101110011100101110101010001000010101100011110')
        """
        if not isinstance(message, str):
            return None

        encoded = cls.compress(message)
        assert message == cls.decompress(encoded)
```

DEFLATE

```
from os import path

class Deflate:
    """
    DEFLATE algorithm.
    """

    def deflate_encode(self, message: str, buffer_size: int = 8192,
to_file = False,
```

```
                    return_dict = False):
        """
        DEFLATE algorithm.

        Args:
            message (str): message to encode
            buffer_size (int): buffer size for lz77 algorithm

        Returns:
            str: encoded str

        >>> defl = Deflate()
        >>> defl.deflate_encode('Hello')
        '11010011010111011000000111'
        """
        lz77 = LZ77()
        huffman = Huffman()
        encoded_lz77 = "".join(
            [f"{offset}{length}{symb or ' '}"
                for offset, length, symb in lz77.compress(message,
buffer_size)]
        )
        encoded_huffman = huffman.encode(encoded_lz77)
        dictionary = huffman.get_dictionary(encoded_lz77)

        if to_file:
            with open('deflate.txt', 'w', encoding='utf-8') as file:
                file.write(encoded_huffman)

        if return_dict:
            return encoded_huffman, dictionary

        return encoded_huffman


    def deflate_decode(self, encoded_str: str, dictionary: DICTIONARY,
buffer_size: int = 5):
        """
        Decoding deflate algorithms.

        Args:
            encoded_str (str): encode message
            buffer_size (int): buffer size for lz77 algorithm

        Returns:
            str: decoded str

        >>> defl = Deflate()
        >>> b, d = defl.deflate_encode('Hello', return_dict = True)
```

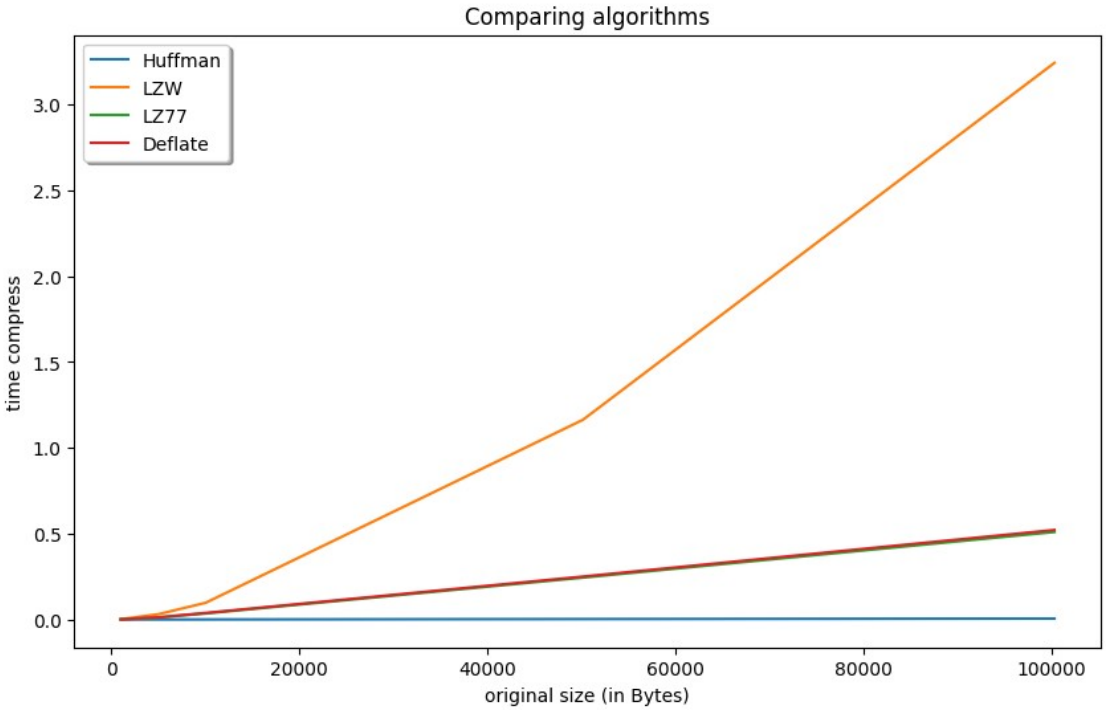
```
        >>> defl.deflate_decode(b, d)
        'Hello'
        """
        if not isinstance(encoded_str, str) or not
isinstance(buffer_size, int):
            return None
        lz77 = LZ77()
        huffman = Huffman()
        decoded_huffman = huffman.decode(encoded_str, dictionary)
        list_of_tuples = [(int(decoded_huffman[i]),
int(decoded_huffman[i + 1]),
                           decoded_huffman[i + 2])
                           for i in range(0, len(decoded_huffman), 3)]
        return lz77.decompress(list_of_tuples, buffer_size)


    @staticmethod
    def read_compress_file(file_path: str):
        """
        Read content from file.

        Args:
            path (str): path to the existing file

        Returns:
            list[tuple[int, int, str]]: compressed message
            (list of tuples with three elements: <offset, lenght,
next>)
        """
        if not isinstance(file_path, str) or not
path.exists(file_path):
            return None

        if not path.isfile(file_path):
            return None

        with open(file_path, 'r', encoding='utf-8') as file:
            content = file.read()

        name = file_path.split('/')[-1].split('.')[0] + '_encoded'

        with open(f'{name}.txt', 'w', encoding='utf-8') as file:
            obj = Deflate()
            file.write(obj.deflate_encode(content))

        return None
```

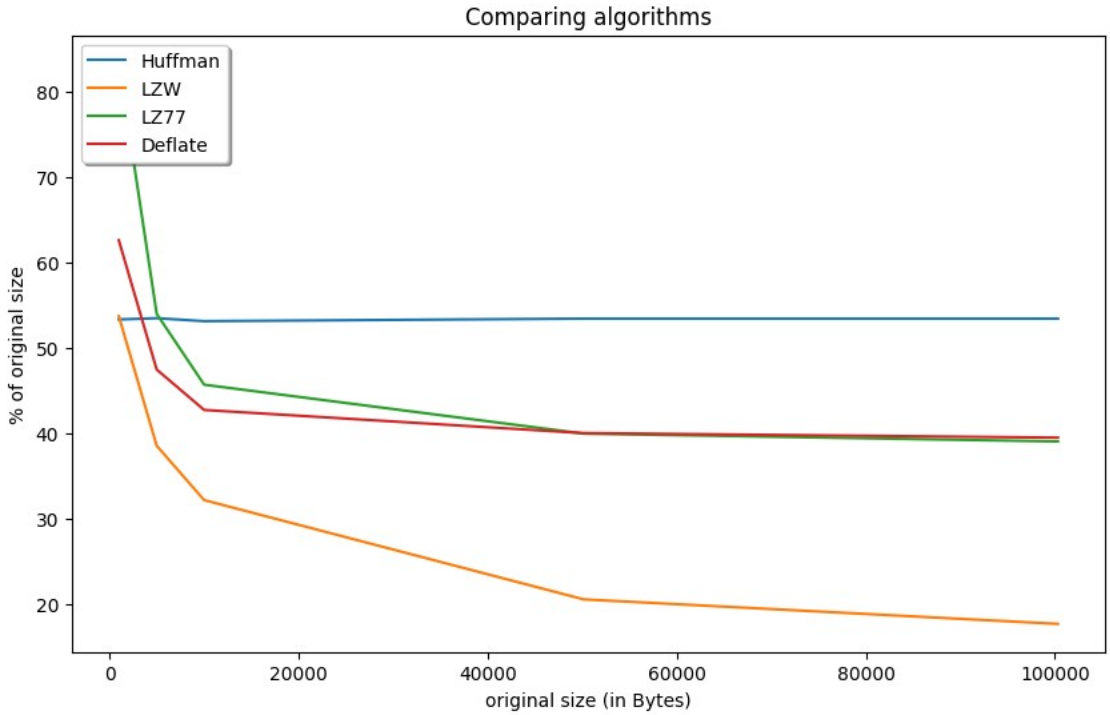
```python
import matplotlib.pyplot as plt
from tqdm import tqdm
import time

def compare_time(func, path: str, iteration: int = 1000):
    """
    Timer for analysing the execution time of algorithms.

    Parameters
    ----------
    func : function
        function for finding shortest paths
    file : int
        path to file to read the content
    iteration : int
        number of iterations

    Returns
    -------
    float
        execution time of the algorithm
    """
    exec_time = 0

    with open(path, 'r', encoding='utf-8') as file:
        content = file.read()

    for _ in tqdm(range(iteration)):
        start = time.time()
        func(message=content)
        end = time.time()

        exec_time += end - start

    return exec_time / iteration

def compare_sizes(func, path, *_):
    with open(path, 'r', encoding='utf-8') as file:
        content = file.read()

    content_size = len(content)
    encoded = func(content)

    if isinstance(encoded, str):
        # if it's str, that is binary code
        # every character codes with 8 bits in ASCII
        # but we code not with ASCII but with own binary codes
        return len(encoded) * 100 / (content_size * 8)

    # it's lz77
```

```
    if isinstance(encoded[0], tuple):
        return 3 * len(encoded) * 100 / content_size


    return len(encoded) * 100 / content_size

def compare(comparison, ylabel: str, iterations: int = 10):
    """
    Compare four algorithms for different size of inputs.
    """
    file_sizes = [1000, 5000, 10000, 50000, 100000]

    plt.figure(figsize=(10,6))
    plt.title("Comparing algorithms")

    sizes = []

    for file_size in file_sizes:
        with open(f"sample{file_size}.txt", 'r') as file:
            text = file.read()
            sizes.append(len(text))

    for fun in (Huffman().encode, LZW().compress, LZ77().compress,
Deflate().deflate_encode):
        algo = [comparison(fun, f"sample{file}.txt", iterations) for
file in file_sizes]
        plt.plot(sizes, algo)

    plt.legend(['Huffman', 'LZW', 'LZ77', "Deflate"], loc='upper
left', shadow=True)
    plt.xlabel('original size (in Bytes)')
    plt.ylabel(ylabel)
    return plt.show()

compare(compare_time, "time to compress")
compare(compare_sizes, "% of original size")
```

```
100%|██████████| 10/10 [00:00<00:00, 9487.23it/s]
100%|██████████| 10/10 [00:00<00:00, 2861.83it/s]
100%|██████████| 10/10 [00:00<00:00, 1381.39it/s]
100%|██████████| 10/10 [00:00<00:00, 343.29it/s]
100%|██████████| 10/10 [00:00<00:00, 173.10it/s]
100%|██████████| 10/10 [00:00<00:00, 413.09it/s]
100%|██████████| 10/10 [00:00<00:00, 31.82it/s]
100%|██████████| 10/10 [00:00<00:00, 10.19it/s]
100%|██████████| 10/10 [00:11<00:00,  1.16s/it]
100%|██████████| 10/10 [00:32<00:00,  3.24s/it]
100%|██████████| 10/10 [00:00<00:00, 862.65it/s]
100%|██████████| 10/10 [00:00<00:00, 81.20it/s]
100%|██████████| 10/10 [00:00<00:00, 27.97it/s]
```

```
100%|██████████| 10/10 [00:02<00:00,  4.09it/s]
100%|██████████| 10/10 [00:05<00:00,  1.96it/s]
100%|██████████| 10/10 [00:00<00:00, 663.08it/s]
100%|██████████| 10/10 [00:00<00:00, 75.98it/s]
100%|██████████| 10/10 [00:00<00:00, 25.82it/s]
100%|██████████| 10/10 [00:02<00:00,  3.99it/s]
100%|██████████| 10/10 [00:05<00:00,  1.92it/s]
```





Contributors:

- Victor Muryn — Huffman and LZW
- Ksenia Kretsula — LZ77 and Deflate