Reversor de Máquina de Turing

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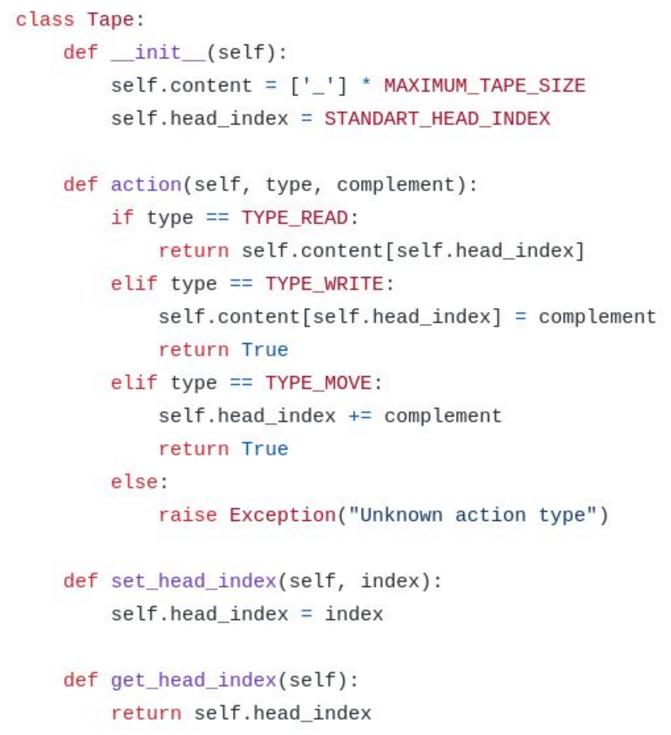
Processador de Máquina de Turing

A. Fita

Unidade básica que representa uma fita, em uma máquina existirão três. Nessa fita é possível ler, escrever e mover o cabeçote.

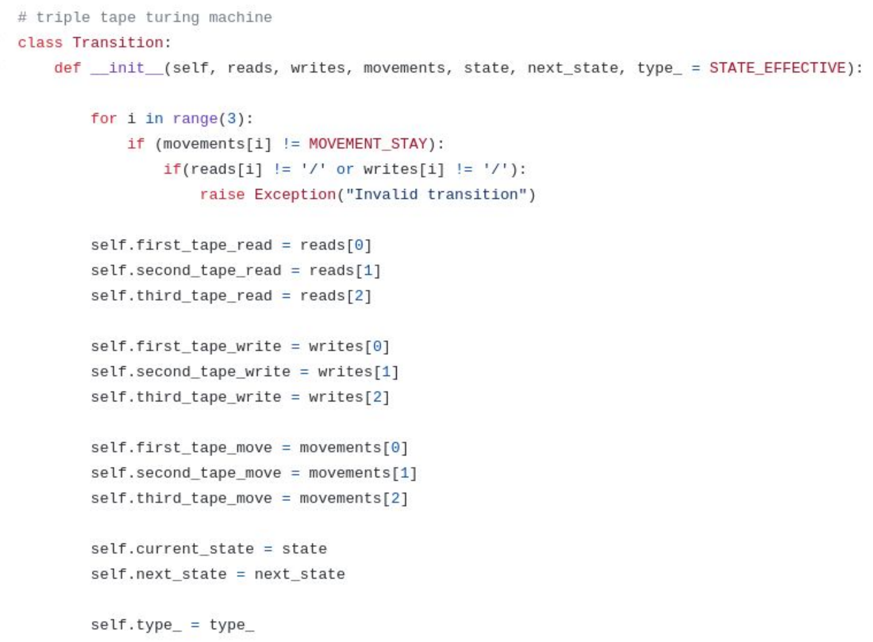


```
class Tape:
    def __init__(self):
        self.content = ['_'] * MAXIMUM_TAPE_SIZE
        self.head_index = STANDART_HEAD_INDEX

    def action(self, type, complement):
        if type == TYPE_READ:
            return self.content[self.head_index]
        elif type == TYPE_WRITE:
            self.content[self.head_index] = complement
            return True
        elif type == TYPE_MOVE:
            self.head_index += complement
            return True
        else:
            raise Exception("Unknown action type")

    def set_head_index(self, index):
        self.head_index = index

    def get_head_index(self):
        return self.head_index
```

Processador de Máquina de Turing

B. Transação

Como a máquina é quadrupla, só é possivel ler/escrever ou mover separadamente.

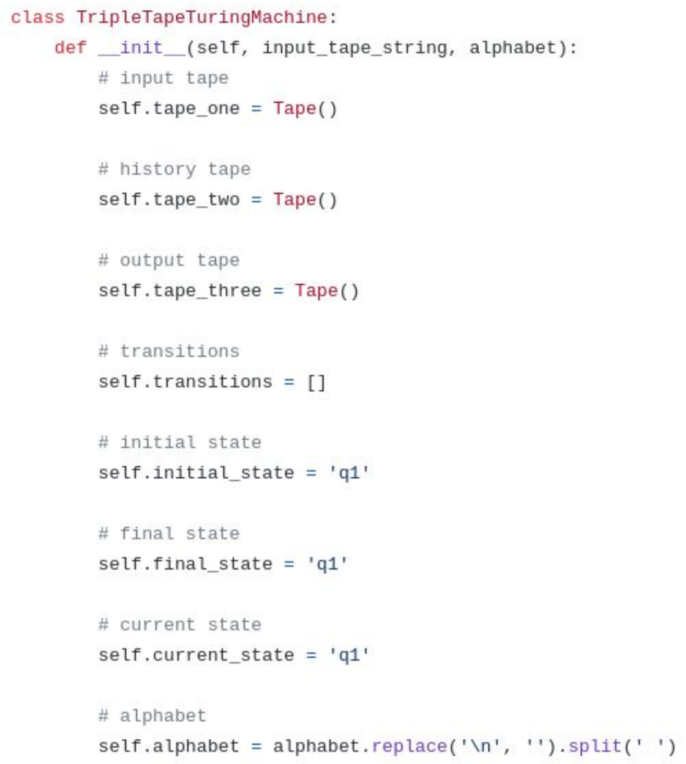


```
# triple tape turing machine
class Transition:
    def __init__(self, reads, writes, movements, state, next_state, type_ = STATE_EFFECTIVE):

        for i in range(3):
            if (movements[i] != MOVEMENT_STAY):
                if(reads[i] != '/' or writes[i] != '/'):
                    raise Exception("Invalid transition")

        self.first_tape_read = reads[0]
        self.second_tape_read = reads[1]
        self.third_tape_read = reads[2]

        self.first_tape_write = writes[0]
        self.second_tape_write = writes[1]
        self.third_tape_write = writes[2]

        self.first_tape_move = movements[0]
        self.second_tape_move = movements[1]
        self.third_tape_move = movements[2]

        self.current_state = state
        self.next_state = next_state

        self.type_ = type_
```

Processador de Máquina de Turing

C. Máquina tripla

A maquina de turing implementada possuí três fitas, transições ilimitadas e informações de estado. Além de algumas funções demonstradas nos próximos slides.

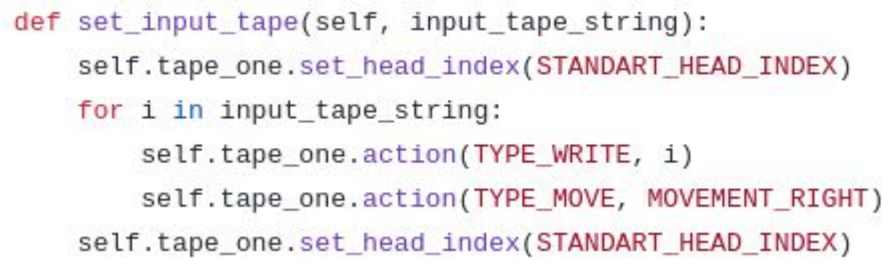


```python
class TripleTapeTuringMachine:
    def __init__(self, input_tape_string, alphabet):
        # input tape
        self.tape_one = Tape()

        # history tape
        self.tape_two = Tape()

        # output tape
        self.tape_three = Tape()

        # transitions
        self.transitions = []

        # initial state
        self.initial_state = 'q1'

        # final state
        self.final_state = 'q1'

        # current state
        self.current_state = 'q1'

        # alphabet
        self.alphabet = alphabet.replace('\n', '').split(' ')
```

Processador de Máquina de Turing

C. Máquina tripla

A função ao lado seta uma string de input na fita de número 1

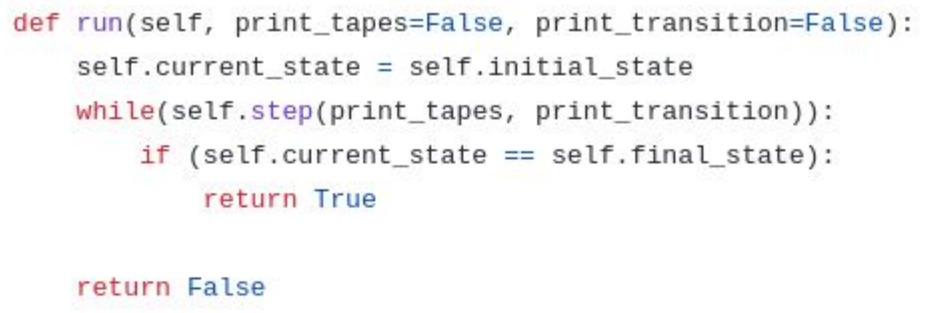


```
def set_input_tape(self, input_tape_string):
    self.tape_one.set_head_index(STANDART_HEAD_INDEX)
    for i in input_tape_string:
        self.tape_one.action(TYPE_WRITE, i)
        self.tape_one.action(TYPE_MOVE, MOVEMENT_RIGHT)
    self.tape_one.set_head_index(STANDART_HEAD_INDEX)
```

Processador de Máquina de Turing

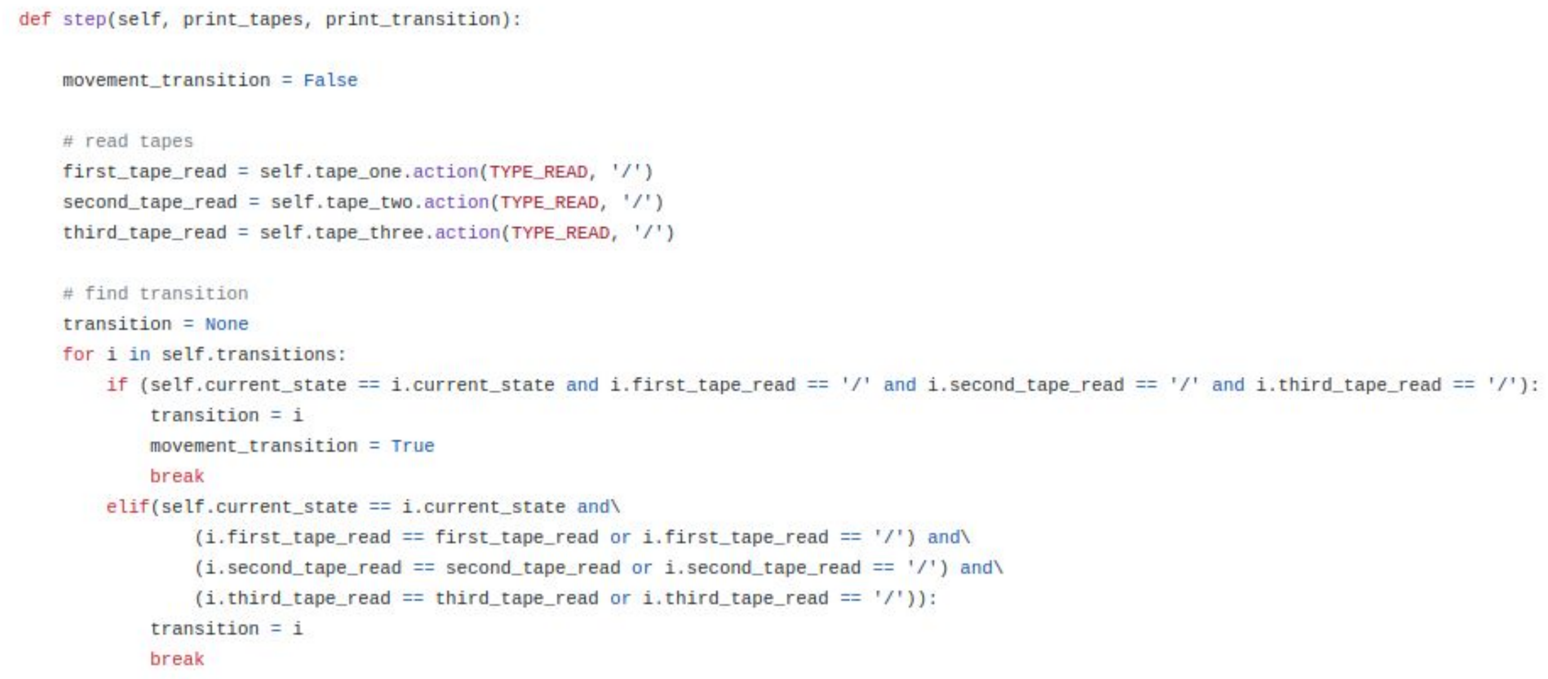
C. Máquina tripla

A função ao lado processa a máquina de turing, juntamente com a função step.



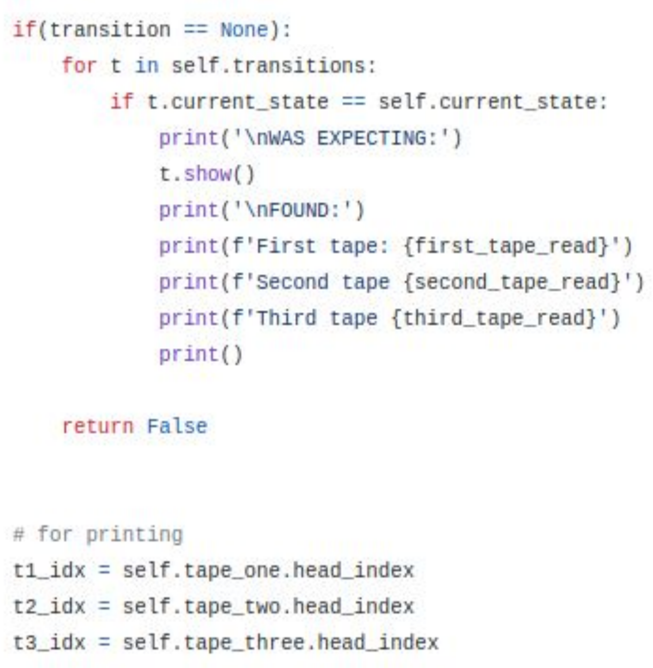
```
def run(self, print_tapes=False, print_transition=False):
    self.current_state = self.initial_state
    while(self.step(print_tapes, print_transition)):
        if (self.current_state == self.final_state):
            return True

    return False
```

Processador de Máquina de Turing

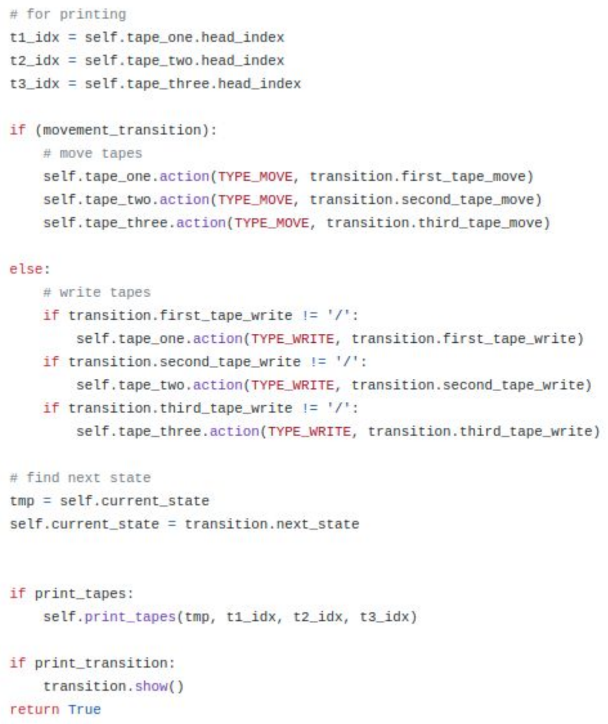


```
def step(self, print_tapes, print_transition):

    movement_transition = False

    # read tapes
    first_tape_read = self.tape_one.action(TYPE_READ, '/')
    second_tape_read = self.tape_two.action(TYPE_READ, '/')
    third_tape_read = self.tape_three.action(TYPE_READ, '/')

    # find transition
    transition = None
    for i in self.transitions:
        if (self.current_state == i.current_state and i.first_tape_read == '/' and i.second_tape_read == '/' and i.third_tape_read == '/'):
            transition = i
            movement_transition = True
            break
        elif(self.current_state == i.current_state and\
                (i.first_tape_read == first_tape_read or i.first_tape_read == '/') and\
                (i.second_tape_read == second_tape_read or i.second_tape_read == '/') and\
                (i.third_tape_read == third_tape_read or i.third_tape_read == '/')):
            transition = i
            break
```

Processador de Máquina de Turing



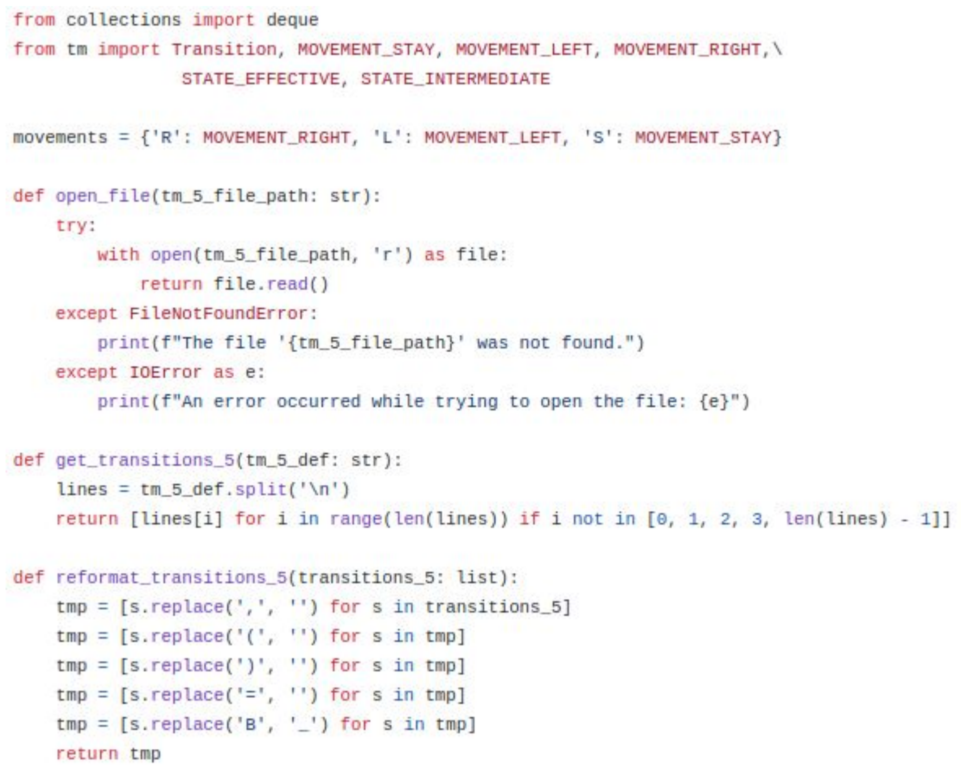
```python
if(transition == None):
    for t in self.transitions:
        if t.current_state == self.current_state:
            print('\nWAS EXPECTING:')
            t.show()
            print('\nFOUND:')
            print(f'First tape: {first_tape_read}')
            print(f'Second tape {second_tape_read}')
            print(f'Third tape {third_tape_read}')
            print()

    return False


# for printing
t1_idx = self.tape_one.head_index
t2_idx = self.tape_two.head_index
t3_idx = self.tape_three.head_index
```



```python
# for printing
t1_idx = self.tape_one.head_index
t2_idx = self.tape_two.head_index
t3_idx = self.tape_three.head_index

if (movement_transition):
    # move tapes
    self.tape_one.action(TYPE_MOVE, transition.first_tape_move)
    self.tape_two.action(TYPE_MOVE, transition.second_tape_move)
    self.tape_three.action(TYPE_MOVE, transition.third_tape_move)

else:
    # write tapes
    if transition.first_tape_write != '/':
        self.tape_one.action(TYPE_WRITE, transition.first_tape_write)
    if transition.second_tape_write != '/':
        self.tape_two.action(TYPE_WRITE, transition.second_tape_write)
    if transition.third_tape_write != '/':
        self.tape_three.action(TYPE_WRITE, transition.third_tape_write)

# find next state
tmp = self.current_state
self.current_state = transition.next_state


if print_tapes:
    self.print_tapes(tmp, t1_idx, t2_idx, t3_idx)

if print_transition:
    transition.show()
return True
```

Parser e Conversor 5-4

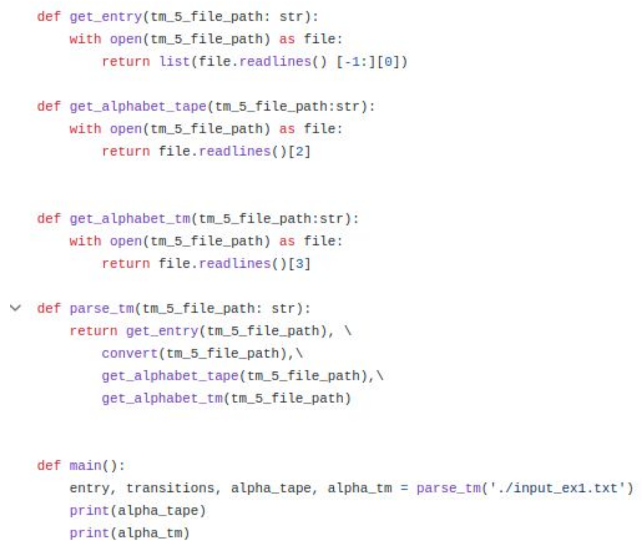
Parser da definição da máquina + conversor de quíntupla para quádrupla



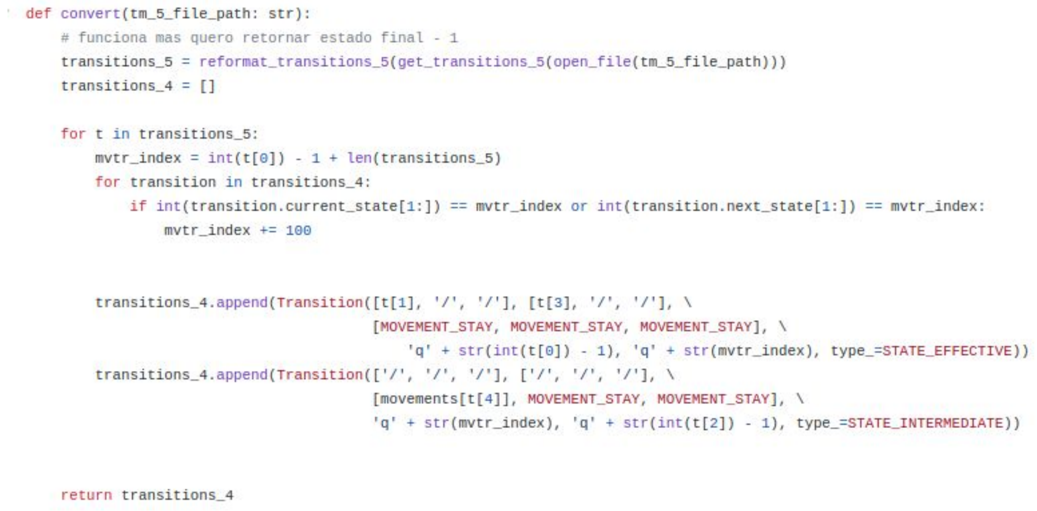
```python
from collections import deque
from tm import Transition, MOVEMENT_STAY, MOVEMENT_LEFT, MOVEMENT_RIGHT,\
                STATE_EFFECTIVE, STATE_INTERMEDIATE

movements = {'R': MOVEMENT_RIGHT, 'L': MOVEMENT_LEFT, 'S': MOVEMENT_STAY}

def open_file(tm_5_file_path: str):
    try:
        with open(tm_5_file_path, 'r') as file:
            return file.read()
    except FileNotFoundError:
        print(f"The file '{tm_5_file_path}' was not found.")
    except IOError as e:
        print(f"An error occurred while trying to open the file: {e}")

def get_transitions_5(tm_5_def: str):
    lines = tm_5_def.split('\n')
    return [lines[i] for i in range(len(lines)) if i not in [0, 1, 2, 3, len(lines) - 1]]

def reformat_transitions_5(transitions_5: list):
    tmp = [s.replace(',', '') for s in transitions_5]
    tmp = [s.replace('(', '') for s in tmp]
    tmp = [s.replace(')', '') for s in tmp]
    tmp = [s.replace('=', '') for s in tmp]
    tmp = [s.replace('B', '_') for s in tmp]
    return tmp
```

Parser e Conversor 5-4

Parser da definição da máquina + conversor de quíntupla para quádrupla



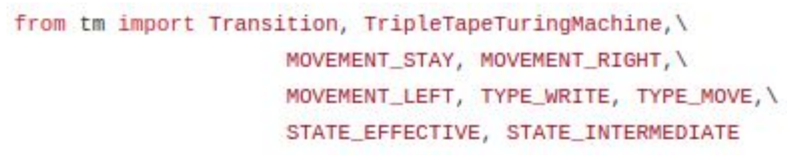
```python
def get_entry(tm_5_file_path: str):
    with open(tm_5_file_path) as file:
        return list(file.readlines() [-1:][0])

def get_alphabet_tape(tm_5_file_path:str):
    with open(tm_5_file_path) as file:
        return file.readlines()[2]


def get_alphabet_tm(tm_5_file_path:str):
    with open(tm_5_file_path) as file:
        return file.readlines()[3]

def parse_tm(tm_5_file_path: str):
    return get_entry(tm_5_file_path), \
        convert(tm_5_file_path),\
        get_alphabet_tape(tm_5_file_path),\
        get_alphabet_tm(tm_5_file_path)


def main():
    entry, transitions, alpha_tape, alpha_tm = parse_tm('./input_ex1.txt')
    print(alpha_tape)
    print(alpha_tm)
```



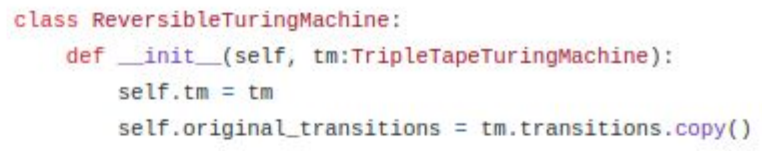
```python
def convert(tm_5_file_path: str):
    # funciona mas quero retornar estado final - 1
    transitions_5 = reformat_transitions_5(get_transitions_5(open_file(tm_5_file_path)))
    transitions_4 = []

    for t in transitions_5:
        mvtr_index = int(t[0]) - 1 + len(transitions_5)
        for transition in transitions_4:
            if int(transition.current_state[1:]) == mvtr_index or int(transition.next_state[1:]) == mvtr_index:
                mvtr_index += 100


        transitions_4.append(Transition([t[1], '/', '/'], [t[3], '/', '/'], \
                                        [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], \
                                            'q' + str(int(t[0]) - 1), 'q' + str(mvtr_index), type_=STATE_EFFECTIVE))
        transitions_4.append(Transition(['/', '/', '/'], ['/', '/', '/'], \
                                        [movements[t[4]], MOVEMENT_STAY, MOVEMENT_STAY], \
                                        'q' + str(mvtr_index), 'q' + str(int(t[2]) - 1), type_=STATE_INTERMEDIATE))


    return transitions_4
```

Máquina Reversível

Classe que recebe uma máquina de turing e tem autofunções que convertem em máquina reversível



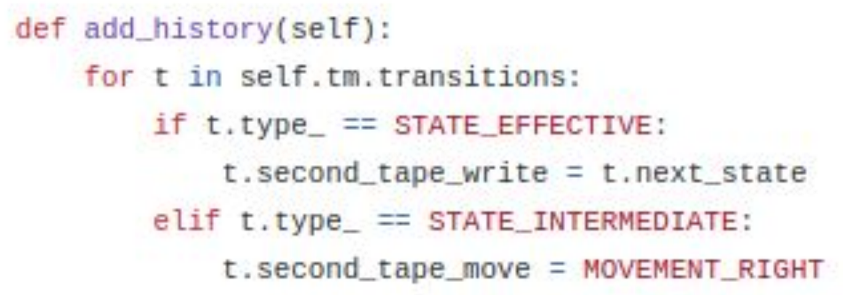
```
from tm import Transition, TripleTapeTuringMachine,\
                    MOVEMENT_STAY, MOVEMENT_RIGHT,\
                    MOVEMENT_LEFT, TYPE_WRITE, TYPE_MOVE,\
                    STATE_EFFECTIVE, STATE_INTERMEDIATE
```



```
class ReversibleTuringMachine:
    def __init__(self, tm:TripleTapeTuringMachine):
        self.tm = tm
        self.original_transitions = tm.transitions.copy()
```

Máquina Reversível

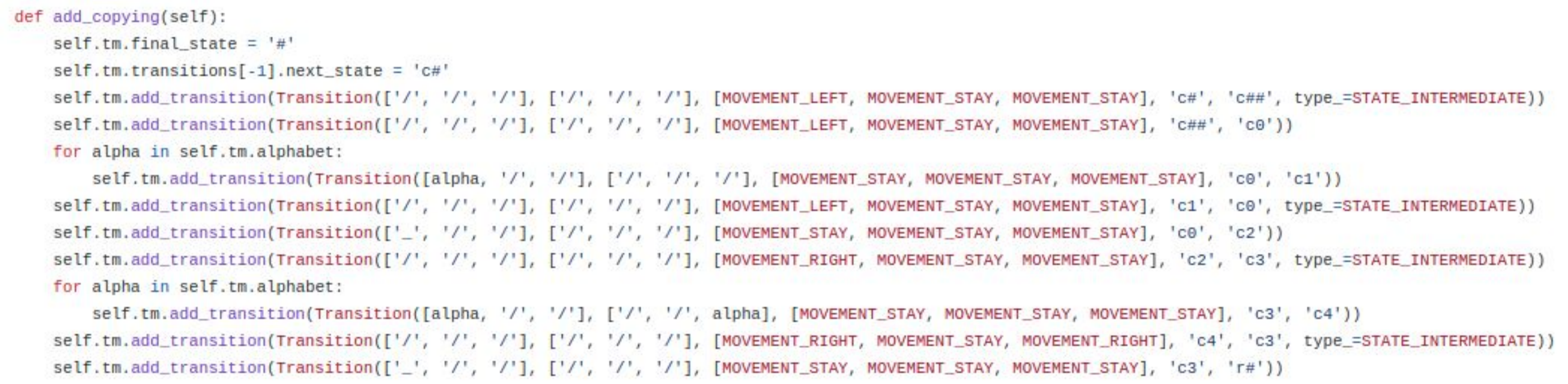
Função para adicionar histórico às transições da máquina



```python
def add_history(self):
    for t in self.tm.transitions:
        if t.type_ == STATE_EFFECTIVE:
            t.second_tape_write = t.next_state
        elif t.type_ == STATE_INTERMEDIATE:
            t.second_tape_move = MOVEMENT_RIGHT
```

Máquina Reversível

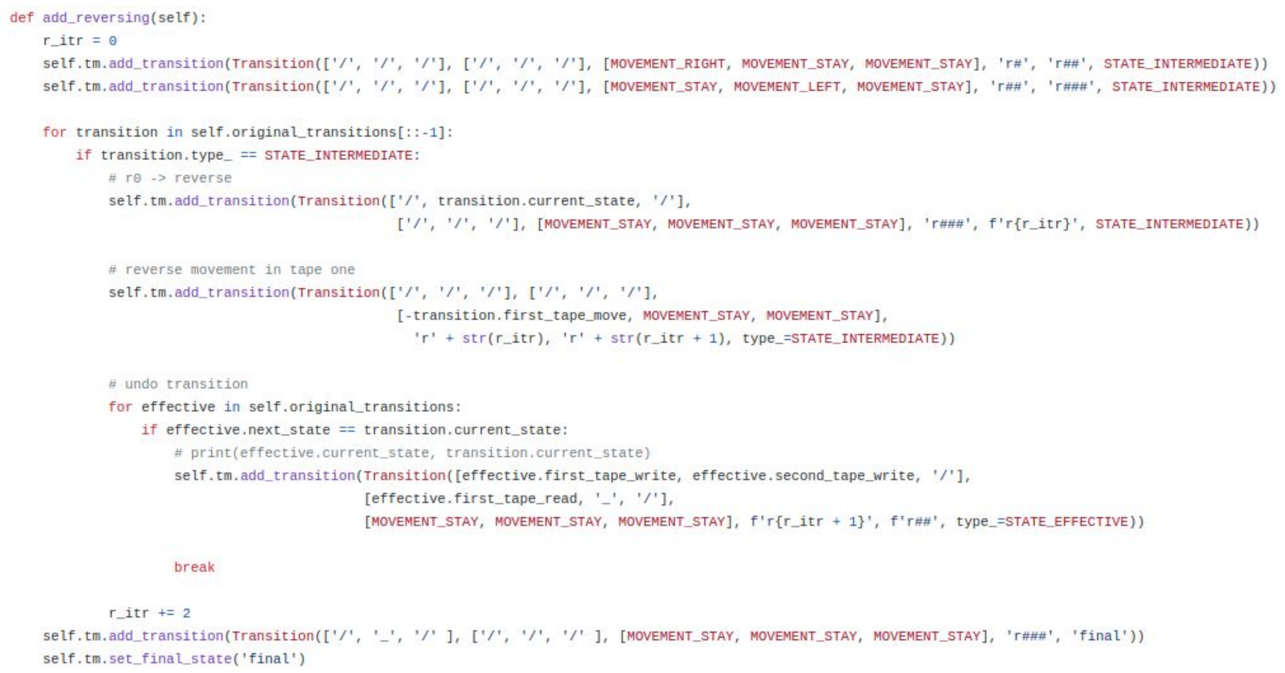
Função que acopla máquina de turing que copia a fita 1 na fita 3



```
def add_copying(self):
    self.tm.final_state = '#'
    self.tm.transitions[-1].next_state = 'c#'
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_LEFT, MOVEMENT_STAY, MOVEMENT_STAY], 'c#', 'c##', type_=STATE_INTERMEDIATE))
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_LEFT, MOVEMENT_STAY, MOVEMENT_STAY], 'c##', 'c0'))
    for alpha in self.tm.alphabet:
        self.tm.add_transition(Transition([alpha, '/', '/'], ['/', '/', '/'], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'c0', 'c1'))
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_LEFT, MOVEMENT_STAY, MOVEMENT_STAY], 'c1', 'c0', type_=STATE_INTERMEDIATE))
    self.tm.add_transition(Transition(['_', '/', '/'], ['/', '/', '/'], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'c0', 'c2'))
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_RIGHT, MOVEMENT_STAY, MOVEMENT_STAY], 'c2', 'c3', type_=STATE_INTERMEDIATE))
    for alpha in self.tm.alphabet:
        self.tm.add_transition(Transition([alpha, '/', '/'], ['/', '/', alpha], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'c3', 'c4'))
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_RIGHT, MOVEMENT_STAY, MOVEMENT_RIGHT], 'c4', 'c3', type_=STATE_INTERMEDIATE))
    self.tm.add_transition(Transition(['_', '/', '/'], ['/', '/', '/'], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'c3', 'r#'))
```

Máquina Reversível

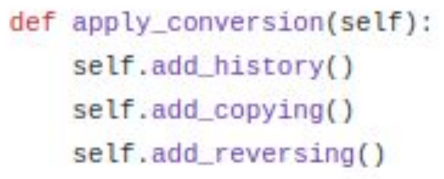
Função que acopla máquina inversora



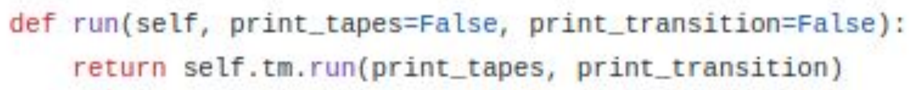
```
def add_reversing(self):
    r_itr = 0
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_RIGHT, MOVEMENT_STAY, MOVEMENT_STAY], 'r#', 'r##', STATE_INTERMEDIATE))
    self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'], [MOVEMENT_STAY, MOVEMENT_LEFT, MOVEMENT_STAY], 'r##', 'r###', STATE_INTERMEDIATE))

    for transition in self.original_transitions[::-1]:
        if transition.type_ == STATE_INTERMEDIATE:
            # r0 -> reverse
            self.tm.add_transition(Transition(['/', transition.current_state, '/'],
                                               ['/', '/', '/'], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'r###', f'r{r_itr}', STATE_INTERMEDIATE))

            # reverse movement in tape one
            self.tm.add_transition(Transition(['/', '/', '/'], ['/', '/', '/'],
                                               [-transition.first_tape_move, MOVEMENT_STAY, MOVEMENT_STAY],
                                                 'r' + str(r_itr), 'r' + str(r_itr + 1), type_=STATE_INTERMEDIATE))

            # undo transition
            for effective in self.original_transitions:
                if effective.next_state == transition.current_state:
                    # print(effective.current_state, transition.current_state)
                    self.tm.add_transition(Transition([effective.first_tape_write, effective.second_tape_write, '/'],
                                                       [effective.first_tape_read, '_', '/'],
                                                       [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], f'r{r_itr + 1}', f'r##', type_=STATE_EFFECTIVE))

                    break

            r_itr += 2
    self.tm.add_transition(Transition(['/', '_', '/' ], ['/', '/', '/' ], [MOVEMENT_STAY, MOVEMENT_STAY, MOVEMENT_STAY], 'r###', 'final'))
    self.tm.set_final_state('final')
```

Máquina Reversível

Função que transforma a máquina de turing com ajuda das outras e método run



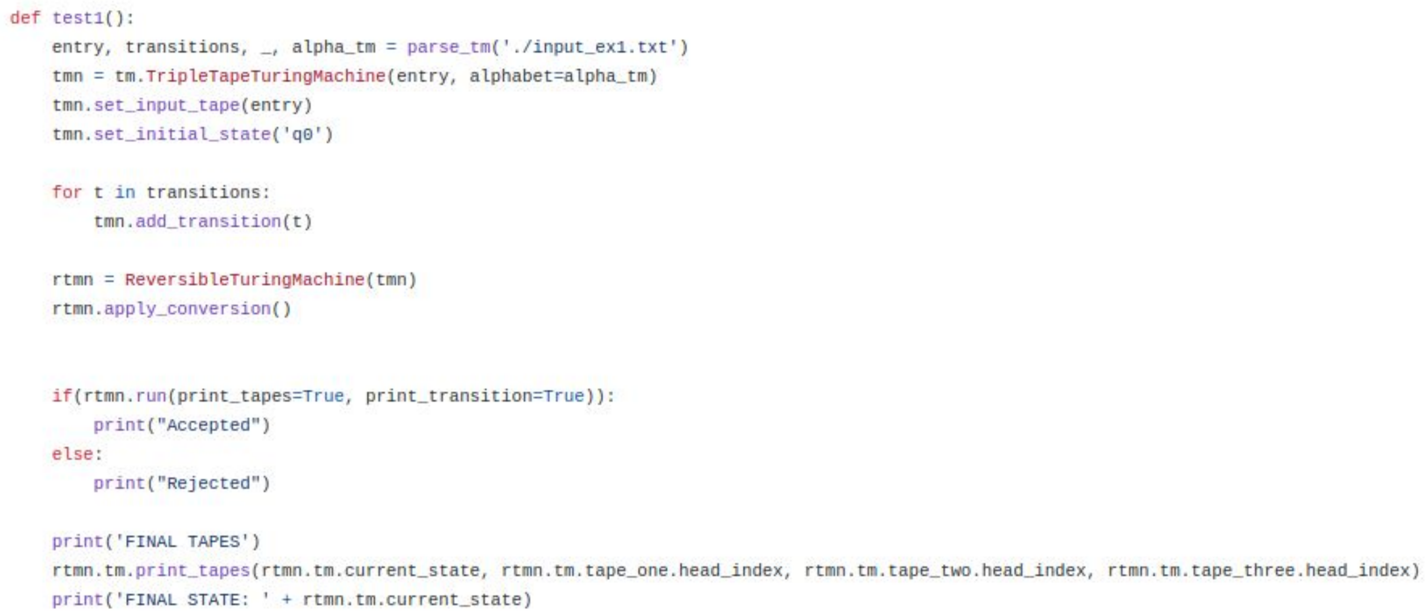
```python
def apply_conversion(self):
    self.add_history()
    self.add_copying()
    self.add_reversing()
```



```python
def run(self, print_tapes=False, print_transition=False):
    return self.tm.run(print_tapes, print_transition)
```

Rodando o código

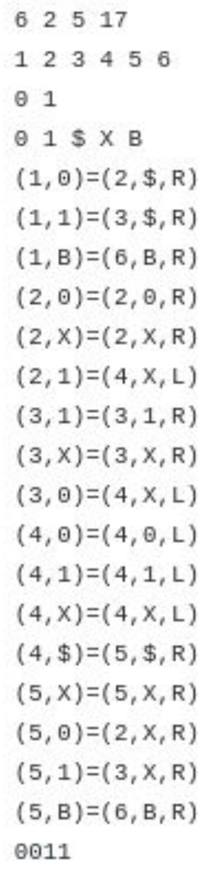
Rodando tudo



```python
def test1():
    entry, transitions, _, alpha_tm = parse_tm('./input_ex1.txt')
    tmn = tm.TripleTapeTuringMachine(entry, alphabet=alpha_tm)
    tmn.set_input_tape(entry)
    tmn.set_initial_state('q0')

    for t in transitions:
        tmn.add_transition(t)

    rtmn = ReversibleTuringMachine(tmn)
    rtmn.apply_conversion()


    if(rtmn.run(print_tapes=True, print_transition=True)):
        print("Accepted")
    else:
        print("Rejected")

    print('FINAL TAPES')
    rtmn.tm.print_tapes(rtmn.tm.current_state, rtmn.tm.tape_one.head_index, rtmn.tm.tape_two.head_index, rtmn.tm.tape_three.head_index)
    print('FINAL STATE: ' + rtmn.tm.current_state)
```

Input + Output

- Input



```
6 2 5 17
1 2 3 4 5 6
0 1
0 1 $ X B
(1,0)=(2,$,R)
(1,1)=(3,$,R)
(1,B)=(6,B,R)
(2,0)=(2,0,R)
(2,X)=(2,X,R)
(2,1)=(4,X,L)
(3,1)=(3,1,R)
(3,X)=(3,X,R)
(3,0)=(4,X,L)
(4,0)=(4,0,L)
(4,1)=(4,1,L)
(4,X)=(4,X,L)
(4,$)=(5,$,R)
(5,X)=(5,X,R)
(5,0)=(2,X,R)
(5,1)=(3,X,R)
(5,B)=(6,B,R)
0011
```

```
T1 = ['_', '_', '_', '_', '_'](q0)['$', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](q0)['q17', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q0)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = 0 $ 0
Second tape = / q17 0
Third tape = / / 0
Current state = q0
Next state = q17
Type = 0

T1 = ['_', '_', '_', '_', '_'](q17)['0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](q17)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q17)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 1
Third tape = / / 0
Current state = q17
Next state = q1
Type = 1

T1 = ['_', '_', '_', '_', '_', '$'](q1)['0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17'](q1)['q18', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q1)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = 0 0 0
Second tape = / q18 0
Third tape = / / 0
Current state = q1
Next state = q18
Type = 0
```

```
T1 = ['_', '_', '_', '_', '_', '$'](q18)['1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17'](q18)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q18)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 1
Third tape = / / 0
Current state = q18
Next state = q1
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', '0'](q1)['X', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18'](q1)['q218', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q1)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = 1 X 0
Second tape = / q218 0
Third tape = / / 0
Current state = q1
Next state = q218
Type = 0

T1 = ['_', '_', '_', '_', '_', '$', '0'](q218)['0', 'X', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18'](q218)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q218)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / -1
Second tape = / / 1
Third tape = / / 0
Current state = q218
Next state = q3
Type = 1
```

```
T1 = ['_', '_', '_', '_', '_', '$', 'X'](q1)['X', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121'](q1)['q118', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q1)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = X X 0
Second tape = / q118 0
Third tape = / / 0
Current state = q1
Next state = q118
Type = 0

T1 = ['_', '_', '_', '_', '_', '$', 'X'](q118)['1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121'](q118)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q118)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 1
Third tape = / / 0
Current state = q118
Next state = q1
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X'](q1)['X', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118'](q1)['q218', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q1)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = 1 X 0
Second tape = / q218 0
Third tape = / / 0
Current state = q1
Next state = q218
Type = 0
```

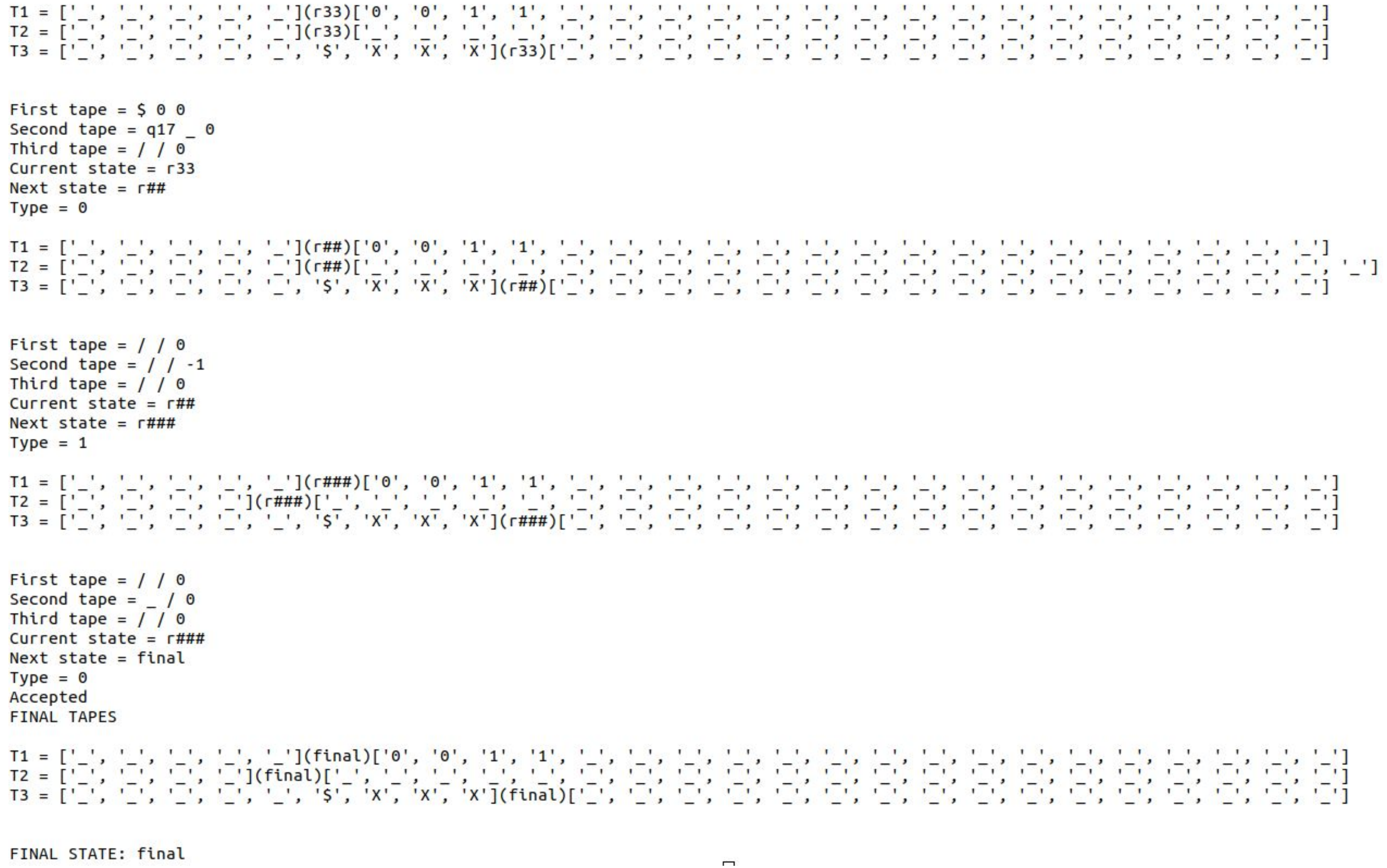
```
T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](q4)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21'](q4)['q321', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q4)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = _ _ 0
Second tape = / q321 0
Third tape = / / 0
Current state = q4
Next state = q321
Type = 0

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](q321)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21'](q321)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](q321)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 1
Third tape = / / 0
Current state = q321
Next state = c#
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X', '_'](c#)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c#)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](c#)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / -1
Second tape = / / 0
Third tape = / / 0
Current state = c#
Next state = c##
Type = 1
```

```
T1 = ['_', '_', '_', '_', '_'](c3)['$', 'X', 'X', 'X', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c3)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](c3)['$', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = $ / 0
Second tape = / / 0
Third tape = / $ 0
Current state = c3
Next state = c4
Type = 0

T1 = ['_', '_', '_', '_', '_'](c4)['X', 'X', 'X', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c4)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_'](c4)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 0
Third tape = / / 1
Current state = c4
Next state = c3
Type = 1

T1 = ['_', '_', '_', '_', '_', '$'](c3)['X', 'X', 'X', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c3)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$'](c3)['X', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = X / 0
Second tape = / / 0
Third tape = / X 0
Current state = c3
Next state = c4
Type = 0
```

```
T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X'](c4)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c4)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X'](c4)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 0
Third tape = / / 1
Current state = c4
Next state = c3
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](c3)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](c3)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](c3)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = _ / 0
Second tape = / / 0
Third tape = / / 0
Current state = c3
Next state = r#
Type = 0

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r#)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121', 'q118', 'q218', 'q220', 'q220', 'q320', 'q21', 'q21', 'q21', 'q321'](r#)['_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r#)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 1
Second tape = / / 0
Third tape = / / 0
Current state = r#
Next state = r##
Type = 1
```

```
T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X'](r###)['1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121'](r###)['q118', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r###)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 0
Second tape = q118 / 0
Third tape = / / 0
Current state = r###
Next state = r24
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', 'X', 'X'](r24)['X', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121'](r24)['q118', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r24)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / -1
Second tape = / / 0
Third tape = / / 0
Current state = r24
Next state = r25
Type = 1

T1 = ['_', '_', '_', '_', '_', '$', 'X'](r25)['X', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17', 'q18', 'q218', 'q20', 'q320', 'q121'](r25)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r25)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = X X 0
Second tape = q118 _ 0
Third tape = / / 0
Current state = r25
Next state = r##
Type = 0
```

```
T1 = ['_', '_', '_', '_', '_', '$'](r##)['0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_', 'q17'](r##)['q17', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r##)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 0
Second tape = / / -1
Third tape = / / 0
Current state = r##
Next state = r###
Type = 1

T1 = ['_', '_', '_', '_', '_', '$'](r###)['0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](r###)['q17', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r###)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 0
Second tape = q17 / 0
Third tape = / / 0
Current state = r###
Next state = r32
Type = 1

T1 = ['_', '_', '_', '_', '_', '$'](r32)['$', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](r32)['q17', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r32)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / -1
Second tape = / / 0
Third tape = / / 0
Current state = r32
Next state = r33
Type = 1
```



```
T1 = ['_', '_', '_', '_', '_'](r33)['0', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](r33)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r33)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = $ 0 0
Second tape = q17 _ 0
Third tape = / / 0
Current state = r33
Next state = r##
Type = 0

T1 = ['_', '_', '_', '_', '_'](r##)['0', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_', '_'](r##)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r##)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 0
Second tape = / / -1
Third tape = / / 0
Current state = r##
Next state = r###
Type = 1

T1 = ['_', '_', '_', '_', '_'](r###)['0', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_'](r###)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](r###)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


First tape = / / 0
Second tape = _ / 0
Third tape = / / 0
Current state = r###
Next state = final
Type = 0
Accepted
FINAL TAPES

T1 = ['_', '_', '_', '_', '_'](final)['0', '0', '1', '1', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T2 = ['_', '_', '_', '_'](final)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']
T3 = ['_', '_', '_', '_', '_', '$', 'X', 'X', 'X'](final)['_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_', '_']


FINAL STATE: final
```