中国地质大学
CHINA UNIVERSITY OF GEOSCIENCES

Data Structure Course Projects Report

Class：19G212

Student ID：20211002548

Name：Shuang Liang

Supervisor：Guilin Li

Date：2022.07.07

1. Discrete Event Simulation: Customs Checkpoint Simulation System

1.1 Course project topics and requirements

【Problem Description】

Consider a customs checkpoint responsible for checking transit vehicles and develop a concrete simulation system. For this system, the following basic considerations are assumed:
(1) The duty of the customs is to check the passing vehicles, here only one direction of traffic inspection is simulated.
(2) Assuming that vehicles arrive at a certain rate, there is a certain randomness, and a vehicle arrives every a to b minutes.
(3) The customs has k inspection channels, and it takes c to d minutes to inspect a vehicle.
(4) Arriving vehicles wait in line on a dedicated line. Once an inspection channel is free, the first vehicle in the queue will enter the channel for inspection. If a vehicle arrives with an empty lane and there is no waiting vehicle, it immediately enters the lane and starts checking.
(5) The desired data include the average waiting time of vehicles and the average time passing through checkpoints.

【Basic Requirements】

The system needs to simulate the inspection process at a customs checkpoint and output a series of events, as well as the average queuing time and average transit time for vehicles.

【Extended Requirements】

Please modify the customs checkpoint simulation system to use a management strategy of one waiting queue per inspection channel. Do some simulations of this new strategy and compare the simulation results with the strategy of sharing the waiting queue.

1.2 Requirement Analysis

1.2.1 Input

Users inputs the precise year, month, day, hour, minute and second from the drop-down date selector of the graphical interactive interface, simulates the start time and end time, and inputs the values of a, b, c, d and k.

1.2.2 Output

The simulated events at the current time and the corresponding time are output in chronological order, and the average waiting time of the vehicle and the average time of passing the checkpoint are output at the end.

1.2.3 Function

Simulate customs inspection, simulate the arrival, inspection and departure of inspection vehicles according to the input time and the values of parameters a, b, c, d and k, and calculate the average waiting time of vehicles and the average time of passing through the inspection station.

1.3 Design

1.3.1 Design Idea

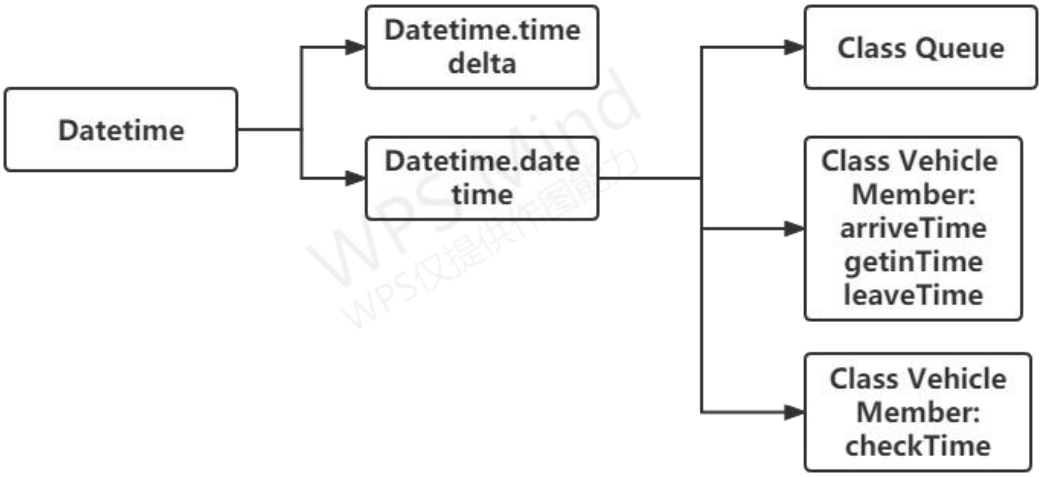
1.3.1.1 Data Structure Dsesign

1.3.1.1.1 Storage Structure Design

Python built in library Datetime.datetime,Used to store and calculate accurate time.
Python built in library Datetime.timedelta,Used to store and calculate precise time intervals.
Custom class Queue,Realize circular queue, which is used to simulate the queue waiting for customs inspection.
Custom class Vehicle，Simulate vehicles waiting for inspection，data members are：number(Vehicle number,int type),arriveTime,checkTime（Time interval required for inspection）,getinTime（Time to start inspection）,leaveTime（Departure time）.

Class Vehicle		
Data member	Member type	Significance
number	int	Vehicle number
arriveTime	Datetime.datetime	arrival time
checkTime	Datetime.timedelta	Time interval required for inspection
getinTime	Datetime.datetime	Time to start inspection
leaveTime	Datetime.datetime	Departure time

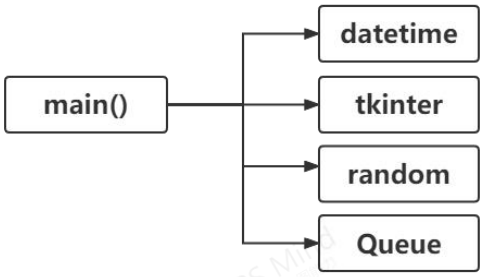
1.3.1.1.2 Logical Structure Design

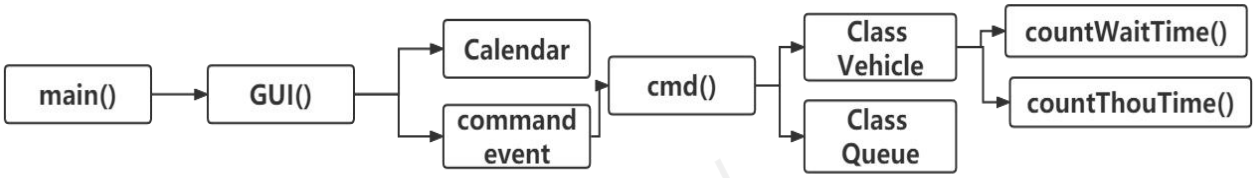


1.3.1.2 Algorithm Design

(1) Preprocess the random number of each vehicle Arrivetime (datetime.timedelta type), vehicle Checktime (datetime.timedelta type) and its number, and store the vehicle in the list.
(2) List of vehicles [i] Arrivetime (datetime.timedelta type) sums the prefixes to get the specific arrival time of each vehicle vehicles[i] Arrivetime (datetime.datetime type).
(3) Starting from the start time, traverse every integer minute until the end time.
(4) While traversing the time, judge vehicles[i] Whether arrivetime is the current time. If so, vehicles[i] Join the waiting queue.
Judge whether the inspection queue is full. If it is not, it will wait for the header element of the queue to leave the queue, and record the start of inspection Time (vehicle.getintime).
Judge whether the inspection of the head element of the inspection queue has been completed. If it is completed, it will be out of the queue and the departure time (vehicle.leavetime) will be recorded.
（5）Count and output the average waiting time and average passing time of each vehicle

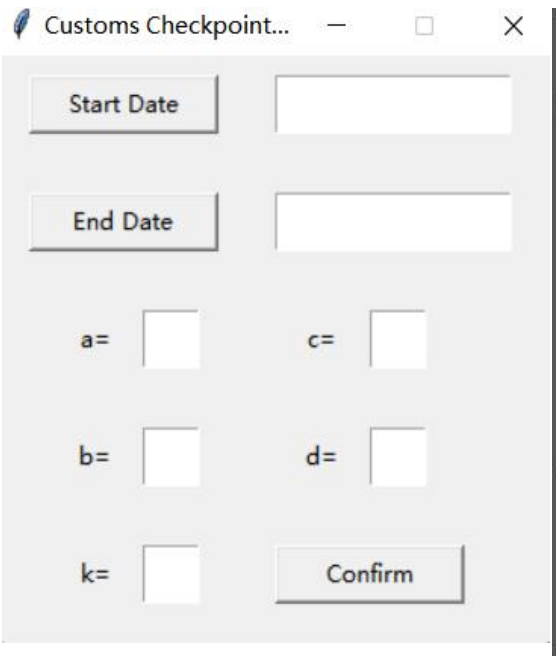
1.3.2 Design representation

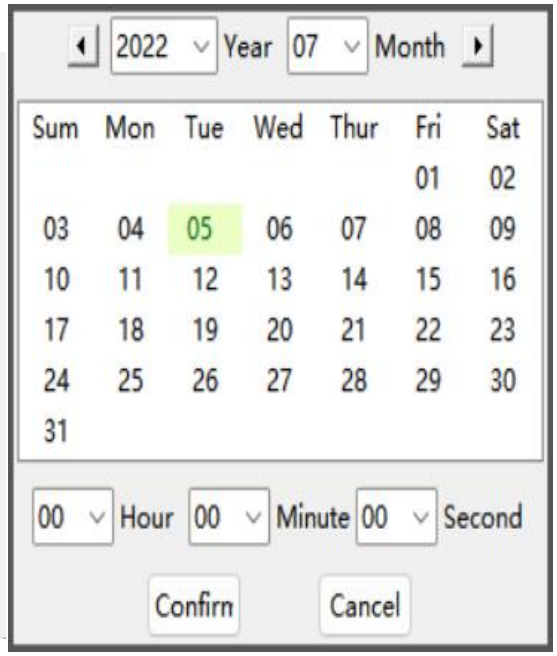




1.3.3 Detailed Design

1.3.3.1 Interface Design





1.3.3.2 Core Algorithm Design

```
    #End at end time
while   (currentTime <= endTime):
    #Judge whether there are vehicles arriving at this time
if (vehicles[i].arriveTime<=currentTime) then
                #Vehicles enter the waiting queue
            waitQueue.enqueue(vehicles[i])
                #Record arrival time
            Record currentTime as arriveTime
                #Print arrival events
            Print arrive event
            #Judge whether the check queue is full
        if (not checkQueue.full()) and (not waitQueue.empty())
                #Vehicles leave the waiting queue
            waitQueue.dequeue()
#The vehicle enters the inspection queue
checkQueue.enqueue()
                #Record the time when the inspection started
            Record current time as getinTime
            #Judge whether the check queue is empty
        if (not checkQueue.empty()) then
                #Judge whether there are vehicles leaving at this time
            If   checkQueue.peek().getinTime and
                    #Judge whether the check queue is empty
                checkQueue.peek().checkTime>=currentTime then
                #Vehicle leaves the inspection queue
            checkQueue.dequeue()
                    #Record the departure time
                Record currentTime as  leaveTime
                    #Print vehicle departure event
                Print leave event
            #Simulate the next minute
        currentTime+=1 min
```

1.4 Debugging Analysis

1.4.1 Problems encountered and Solutions

1.4.1.1 Problems encountered

(1) The date is entered interactively in the graphical interface.

(2) The graphical interface is difficult to transfer data to the core algorithm.

(3) Convert the obtained time string into a datetime object.

1.4.1.2 Solutions

(1) Customize the drop-down calendar space calendar class.

(2) The core algorithm is encapsulated into a function and triggered by button events.

(3) Use format controllers or regular expressions.

1.4.2 Time and Spatial Complexity Analysis

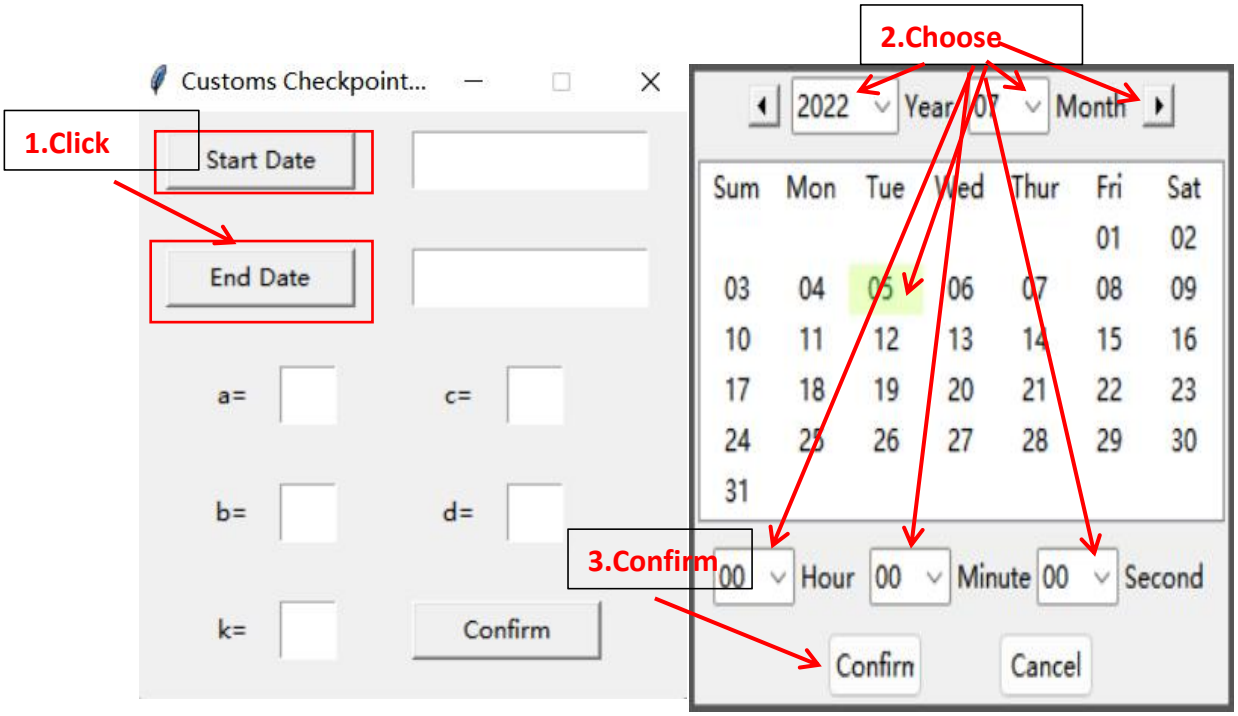
Time complexity：O(N)
Spatial complexity：O(N)

1.4.3 Improved Algorithm

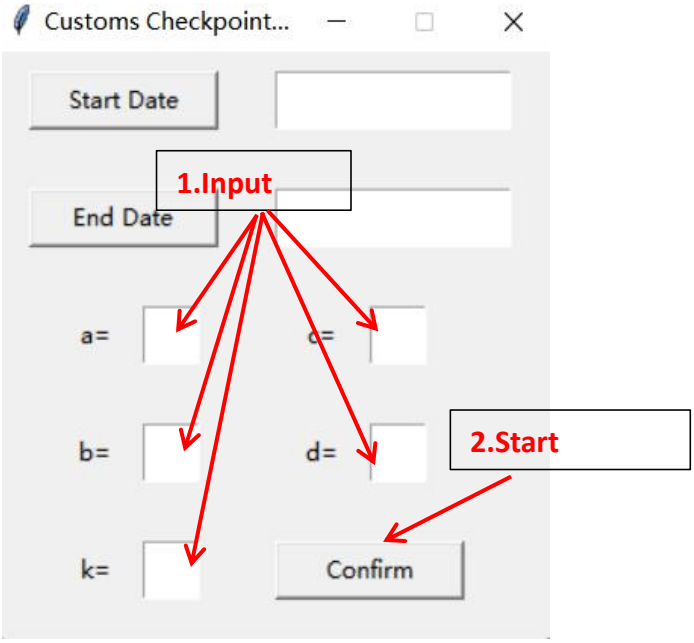
Customize the customs inspection channel class, use the blocking queue, and so on.

1.5 User 's Manual

1.5.1 Enter Start and End Dates



1.5.2 Enter other parameters



1.6 Test Data and Test Results

1.6.1 Test Case

Parameter	Value	Parameter	Value
startTime	2022-07-05 00:00:00	c	10
endTime	2022-07-05 06:00:00	d	3
a	5	k	5
b	3		

1.6.2 Output Results

2022-07-05 00:05:00
Event: Vehicle 1 arrive at the custom
2022-07-05 00:05:00
Event: Vehicle 0 leave the custom
2022-07-05 00:15:00
Event: Vehicle 2 arrive at the custom
2022-07-05 00:15:00
Event: Vehicle 1 leave the custom
2022-07-05 00:21:00
Event: Vehicle 3 arrive at the custom
2022-07-05 00:21:00
Event: Vehicle 2 leave the custom
2022-07-05 00:30:00
Event: Vehicle 4 arrive at the custom
2022-07-05 00:30:00
Event: Vehicle 3 leave the custom
2022-07-05 00:39:00
Event: Vehicle 5 arrive at the custom
2022-07-05 00:39:00
Event: Vehicle 4 leave the custom
2022-07-05 00:45:00
Event: Vehicle 6 arrive at the custom
2022-07-05 00:45:00
Event: Vehicle 5 leave the custom
2022-07-05 00:51:00
Event: Vehicle 7 arrive at the custom
2022-07-05 00:51:00
Event: Vehicle 6 leave the custom
2022-07-05 00:59:00
Event: Vehicle 8 arrive at the custom
2022-07-05 00:59:00
Event: Vehicle 7 leave the custom
2022-07-05 01:06:00
Event: Vehicle 9 arrive at the custom
2022-07-05 01:06:00
Event: Vehicle 8 leave the custom
2022-07-05 01:16:00
Event: Vehicle 10 arrive at the custom
2022-07-05 01:16:00
Event: Vehicle 9 leave the custom
2022-07-05 01:23:00
Event: Vehicle 11 arrive at the custom
2022-07-05 01:23:00
Event: Vehicle 10 leave the custom
2022-07-05 01:31:00
Event: Vehicle 12 arrive at the custom
2022-07-05 01:31:00
Event: Vehicle 11 leave the custom
2022-07-05 01:41:00
Event: Vehicle 13 arrive at the custom
2022-07-05 01:41:00
Event: Vehicle 12 leave the custom
2022-07-05 01:50:00
Event: Vehicle 14 arrive at the custom
2022-07-05 01:50:00
Event: Vehicle 13 leave the custom
2022-07-05 01:56:00
Event: Vehicle 15 arrive at the custom

2022-07-05 01:56:00
Event: Vehicle 14 leave the custom
2022-07-05 02:01:00
Event: Vehicle 16 arrive at the custom
2022-07-05 02:01:00
Event: Vehicle 15 leave the custom
2022-07-05 02:10:00
Event: Vehicle 17 arrive at the custom
2022-07-05 02:10:00
Event: Vehicle 16 leave the custom
2022-07-05 02:18:00
Event: Vehicle 18 arrive at the custom
2022-07-05 02:18:00
Event: Vehicle 17 leave the custom
2022-07-05 02:26:00
Event: Vehicle 19 arrive at the custom
2022-07-05 02:26:00
Event: Vehicle 18 leave the custom
2022-07-05 02:31:00
Event: Vehicle 20 arrive at the custom
2022-07-05 02:31:00
Event: Vehicle 19 leave the custom
2022-07-05 02:37:00
Event: Vehicle 21 arrive at the custom
2022-07-05 02:37:00
Event: Vehicle 20 leave the custom
2022-07-05 02:42:00
Event: Vehicle 22 arrive at the custom
2022-07-05 02:42:00
Event: Vehicle 21 leave the custom
2022-07-05 02:50:00
Event: Vehicle 23 arrive at the custom
2022-07-05 02:50:00
Event: Vehicle 22 leave the custom
2022-07-05 02:56:00
Event: Vehicle 24 arrive at the custom
2022-07-05 02:56:00
Event: Vehicle 23 leave the custom
2022-07-05 03:06:00
Event: Vehicle 25 arrive at the custom
2022-07-05 03:06:00
Event: Vehicle 24 leave the custom
2022-07-05 03:15:00
Event: Vehicle 26 arrive at the custom
2022-07-05 03:15:00
Event: Vehicle 25 leave the custom
2022-07-05 03:23:00
Event: Vehicle 27 arrive at the custom
2022-07-05 03:23:00
Event: Vehicle 26 leave the custom
2022-07-05 03:28:00
Event: Vehicle 28 arrive at the custom
2022-07-05 03:28:00
Event: Vehicle 27 leave the custom
2022-07-05 03:34:00
Event: Vehicle 29 arrive at the custom
2022-07-05 03:34:00
Event: Vehicle 28 leave the custom
2022-07-05 03:43:00
Event: Vehicle 30 arrive at the custom
2022-07-05 03:43:00
Event: Vehicle 29 leave the custom
2022-07-05 03:50:00
Event: Vehicle 31 arrive at the custom
2022-07-05 03:50:00
Event: Vehicle 30 leave the custom
2022-07-05 03:56:00
Event: Vehicle 32 arrive at the custom
2022-07-05 03:56:00
Event: Vehicle 31 leave the custom
2022-07-05 04:04:00
Event: Vehicle 33 arrive at the custom
2022-07-05 04:04:00
Event: Vehicle 32 leave the custom
2022-07-05 04:10:00
Event: Vehicle 34 arrive at the custom
2022-07-05 04:10:00
Event: Vehicle 33 leave the custom
2022-07-05 04:20:00
Event: Vehicle 35 arrive at the custom
2022-07-05 04:20:00
Event: Vehicle 34 leave the custom
2022-07-05 04:29:00
Event: Vehicle 36 arrive at the custom
2022-07-05 04:29:00
Event: Vehicle 35 leave the custom
2022-07-05 04:37:00
Event: Vehicle 37 arrive at the custom

2022-07-05 04:37:00
Event: Vehicle 36 leave the custom
2022-07-05 04:44:00
Event: Vehicle 38 arrive at the custom
2022-07-05 04:44:00
Event: Vehicle 37 leave the custom
2022-07-05 04:54:00
Event: Vehicle 39 arrive at the custom
2022-07-05 04:54:00
Event: Vehicle 38 leave the custom
2022-07-05 05:01:00
Event: Vehicle 40 arrive at the custom
2022-07-05 05:01:00
Event: Vehicle 39 leave the custom
2022-07-05 05:09:00
Event: Vehicle 41 arrive at the custom
2022-07-05 05:09:00
Event: Vehicle 40 leave the custom
2022-07-05 05:19:00
Event: Vehicle 42 arrive at the custom
2022-07-05 05:19:00
Event: Vehicle 41 leave the custom
2022-07-05 05:29:00
Event: Vehicle 43 arrive at the custom
2022-07-05 05:29:00
Event: Vehicle 42 leave the custom
2022-07-05 05:36:00
Event: Vehicle 44 arrive at the custom
2022-07-05 05:36:00
Event: Vehicle 43 leave the custom
2022-07-05 05:43:00
Event: Vehicle 45 arrive at the custom
2022-07-05 05:43:00
Event: Vehicle 44 leave the custom
2022-07-05 05:52:00
Event: Vehicle 46 arrive at the custom
2022-07-05 05:52:00
Event: Vehicle 45 leave the custom
2022-07-05 06:00:00
Event: Vehicle 47 arrive at the custom
2022-07-05 06:00:00
Event: Vehicle 46 leave the custom
Average Wait Time: 0:10:00
Average Through Time: 0:07:00

1.7 Source Program List

1.7.1 Time controller Calendar.py

```
import datetime
import calendar
import tkinter as tk
from tkinter import StringVar, ttk
import tkinter.font as tkFont
datetime = calendar.datetime.datetime
timedelta = calendar.datetime.timedelta
class Calendar:
    def __init__(self, point = None):
        # self.root = root
        self.master = tk.Toplevel()
        self.master.withdraw()
        self.master.attributes('-topmost' ,True)
        fwday = calendar.SUNDAY
        year = datetime.now().year
        month = datetime.now().month
        locale = None
        sel_bg = '#ecffc4'
        sel_fg = '#05640e'
        self._date = datetime(year, month, 1)
#The first day of each month
        self._selection = None
#Set as unselected date
        self.G_Frame = ttk.Frame(self.master)
        self._cal = self.__get_calendar(locale,
fwday)
        self.__setup_styles()
#Create a custom style
self.__place_widgets()
```

```
# pack/grid Widget
            self.__config_calendar()
# Adjust calendar columns and installation Tags
# Configure the canvas and the correct binding to
select the date.
            self.__setup_selection(sel_bg, sel_fg)
            #Storage item ID for later insertion.
self._items = [self._calendar.insert('', 'end', values='')
for _ in range(6)]
           #Insert date in the current empty calendar
            self._update()
            self.G_Frame.pack(expand = 1, fill = 'both')
            self.master.overrideredirect(1)
            self.master.update_idletasks()
            width, height =
self.master.winfo_reqwidth(),
self.master.winfo_reqheight()
            self.height=height
            if point:
                x, y = point[0], point[1]
            else:
                x, y = (self.master.winfo_screenwidth()
- width)/2, (self.master.winfo_screenheight() -
height)/2
            self.master.geometry('%dx%d+%d+%d' %
(width, height, x, y)) #Window position centered
            self.master.after(300, self._main_judge)
            self.master.deiconify()
            self.master.focus_set()
            # self.master.mainloop()
            self.master.wait_window()
#Wait should be used here_ Window suspends the
window. If you use mainloop, it may cause many
errors in the main program
        def __get_calendar(self, locale, fwday):
            if locale is None:
                return calendar.TextCalendar(fwday)
            else:
                return
calendar.LocaleTextCalendar(fwday, locale)


        def __setitem__(self, item, value):
            if item in ('year', 'month'):
                raise AttributeError("attribute '%s' is
not writeable" % item)
            elif item == 'selectbackground':
                self._canvas['background'] = value
            elif item == 'selectforeground':

self._canvas.itemconfigure(self._canvas.text,
item=value)
            else:
                self.G_Frame.__setitem__(self, item,
value)
        def __getitem__(self, item):
            if item in ('year', 'month'):
                return getattr(self._date, item)
            elif item == 'selectbackground':
                return self._canvas['background']
            elif item == 'selectforeground':
                return
self._canvas.itemcget(self._canvas.text, 'fill')
            else:
                r = ttk.tclobjs_to_py({item:
ttk.Frame.__getitem__(self, item)})
                return r[item]
        def __setup_styles(self):
            #Custom TTK style
            style = ttk.Style(self.master)
            arrow_layout = lambda dir: (
                [('Button.focus', {'children':
[('Button.%sarrow' % dir, None)]})]
            )
            style.layout('L.TButton',
arrow_layout('left'))
            style.layout('R.TButton',
arrow_layout('right'))
        def __place_widgets(self):
            #Header frame and its widgets
            Input_judgment_num =
self.master.register(self.Input_judgment)
#You need to wrap the function. It's necessary
hframe = ttk.Frame(self.G_Frame)
            gframe = ttk.Frame(self.G_Frame)
            bframe = ttk.Frame(self.G_Frame)
            xframe = ttk.Frame(self.G_Frame)
```

```
        hframe.pack(in_=self.G_Frame, side='top',
pady=5, anchor='center')
        gframe.pack(in_=self.G_Frame, fill=tk.X,
pady=5)
        bframe.pack(in_=self.G_Frame, pady=5)
        xframe.pack(in_=self.G_Frame,
side='bottom', pady=5)

        lbtn = ttk.Button(hframe, style='L.TButton',
command=self._prev_month)
        lbtn.grid(in_=hframe, column=0, row=0,
padx=5)
        rbtn = ttk.Button(hframe, style='R.TButton',
command=self._next_month)
        rbtn.grid(in_=hframe, column=5, row=0,
padx=5)
        #year drop-down box
        self.CB_year = ttk.Combobox(hframe,
width = 5, values = [str(year) for year in
range(datetime.now().year,
datetime.now().year-11,-1)], validate = 'key',
validatecommand = (Input_judgment_num, '%P'))
        self.CB_year.current(0)
        self.CB_year.grid(in_=hframe, column=1,
row=0)
        self.CB_year.bind('<KeyPress>', lambda
event:self._update(event, True))

self.CB_year.bind("<<ComboboxSelected>>",
self._update)
        tk.Label(hframe, text = 'Year', justify =
'left').grid(in_=hframe, column=2, row=0, padx=(0,5))
          #month drop-down box
        self.CB_month = ttk.Combobox(hframe,
width = 3, values = ['%02d' % month for month in
range(1,13)], state = 'readonly')

self.CB_month.current(datetime.now().month - 1)
        self.CB_month.grid(in_=hframe, column=3,
row=0)

self.CB_month.bind("<<ComboboxSelected>>",
self._update)
        tk.Label(hframe, text = 'Month', justify =
'left').grid(in_=hframe, column=4, row=0)
        # Calendar part
        self._calendar = ttk.Treeview(gframe,
show='', selectmode='none', height=7)
        self._calendar.pack(expand=1, fill='both',
side='bottom', padx=5)
        #Time drop-down box
        self.CB_hour = ttk.Combobox(bframe,
width = 3, values = ['%02d' % hour for hour in
range(0,24)], validate = 'key', validatecommand =
(Input_judgment_num, '%P'))
        self.CB_hour.current(0)
        self.CB_hour.grid(in_=bframe, column=0,
row=0)
        self.CB_hour.bind('<KeyPress>', lambda
event:self._update(event, True))

self.CB_hour.bind("<<ComboboxSelected>>",
self._update)
        tk.Label(bframe, text =
'Hour').grid( in_=bframe,column=1, row=0,
padx=(0,5))
        #minute drop-down box
        self.CB_mins = ttk.Combobox(bframe,
width = 3, values = ['%02d' % mins for mins in
range(0,60)], validate = 'key', validatecommand =
(Input_judgment_num, '%P'))
        self.CB_mins.current(0)
        self.CB_mins.grid(in_=bframe, column=2,
row=0)
        self.CB_mins.bind('<KeyPress>', lambda
event:self._update(event, True))

self.CB_mins.bind("<<ComboboxSelected>>",
self._update)
        tk.Label(bframe, text =
'Minute').grid(column=3, row=0)
        #second drop-down box
        self.CB_seconds = ttk.Combobox(bframe,
width = 3, values = ['%02d' % secds for secds in
range(0,60)], validate = 'key', validatecommand =
(Input_judgment_num, '%P'))
        self.CB_seconds.current(0)
```

```
            self.CB_seconds.grid(in_=bframe,
column=4, row=0)
            self.CB_seconds.bind('<KeyPress>', lambda
event:self._update(event, True))

self.CB_seconds.bind("<<ComboboxSelected>>",
self._update)
            tk.Label(bframe, text = 'Second',justify =
'left').grid(column=5, row=0)

            ttk.Button(xframe, text = "Confirm", width
= 6, command = lambda: self._exit(True)).grid(row =
1, column = 0, sticky = 'ns', padx = 20)
            ttk.Button(xframe, text = "Cancel", width =
6, command = self._exit).grid(row = 1, column = 4,
sticky = 'ne', padx = 20)
            tk.Frame(self.G_Frame, bg =
'#565656').place(x = 0, y = 0, relx = 0, rely = 0,
relwidth = 1, relheigh = 2/200)
            tk.Frame(self.G_Frame, bg =
'#565656').place(x = 0, y = 0, relx = 0, rely = 198/200,
relwidth = 1, relheigh = 2/200)
            tk.Frame(self.G_Frame, bg =
'#565656').place(x = 0, y = 0, relx = 0, rely = 0,
relwidth = 2/200, relheigh = 1)
            tk.Frame(self.G_Frame, bg =
'#565656').place(x = 0, y = 0, relx = 198/200, rely = 0,
relwidth = 2/200, relheigh = 1)

        def __config_calendar(self):
            # cols =
self._cal.formatweekheader(3).split()
            cols =
['Sum','Mon','Tue','Wed','Thur','Fri','Sat']
            self._calendar['columns'] = cols
            self._calendar.tag_configure('header',
background='grey90')
            self._calendar.insert('', 'end', values=cols,
tag='header')
            #Adjust its column width
            font = tkFont.Font()
            maxwidth = max(font.measure(col) for col
in cols)
            for col in cols:
                self._calendar.column(col,
width=maxwidth, minwidth=maxwidth,
                    anchor='center')

        def __setup_selection(self, sel_bg, sel_fg):
            def __canvas_forget(evt):
                canvas.place_forget()
                self._selection = None

            self._font = tkFont.Font()
            self._canvas = canvas =
tk.Canvas(self._calendar, background=sel_bg,
borderwidth=0, highlightthickness=0)
            canvas.text = canvas.create_text(0, 0,
fill=sel_fg, anchor='w')
            canvas.bind('<Button-1>', __canvas_forget)
            self._calendar.bind('<Configure>',
__canvas_forget)
            self._calendar.bind('<Button-1>',
self._pressed)

        def _build_calendar(self):
            year, month = self._date.year,
self._date.month
            header = self._cal.formatmonthname(year,
month, 0)
            #Update the date displayed in the calendar
            cal = self._cal.monthdayscalendar(year,
month)
            for indx, item in enumerate(self._items):
                week = cal[indx] if indx < len(cal) else
[]
                fmt_week = [('%02d' % day) if day
else '' for day in week]
                self._calendar.item(item,
values=fmt_week)

        def _show_select(self, text, bbox):
            x, y, width, height = bbox
            textw = self._font.measure(text)
            canvas = self._canvas
            canvas.configure(width = width, height =
height)
```

```
            canvas.coords(canvas.text, (width - textw)/2,
height / 2 - 1)
            canvas.itemconfigure(canvas.text, text=text)
            canvas.place(in_=self._calendar, x=x, y=y)

        def _pressed(self, evt = None, item = None,
column = None, widget = None):
            "" "click somewhere on the calendar." ""
            if not item:
                x, y, widget = evt.x, evt.y, evt.widget
                item = widget.identify_row(y)
                column = widget.identify_column(x)
            if not column or not item in self._items:
               #Click in the weekday row or just outside
the column.
                return
            item_values = widget.item(item)['values']
            if not len(item_values):
#The line of this month is empty.
                return
            text = item_values[int(column[1]) - 1]
            if not text:
                return
            bbox = widget.bbox(item, column)
            if not bbox: #Calendar is not visible yet
                self.master.after(20, lambda :
self._pressed(item = item, column = column, widget =
widget))
                return
            text = '%02d' % text    #day
            self._selection = (text, item, column)
            self._show_select(text, bbox)

        def _prev_month(self):
            "" "update the calendar to show the previous
month." ""
            self._canvas.place_forget()
            self._selection = None
            self._date = self._date - timedelta(days=1)
            self._date = datetime(self._date.year,
self._date.month, 1)
            self.CB_year.set(self._date.year)
            self.CB_month.set(self._date.month)
            self._update()

        def _next_month(self):
            "" "update the calendar to show the next
month." ""
            self._canvas.place_forget()
            self._selection = None

            year, month = self._date.year,
self._date.month
            self._date = self._date + timedelta(
                days=calendar.monthrange(year,
month)[1] + 1)
            self._date = datetime(self._date.year,
self._date.month, 1)
            self.CB_year.set(self._date.year)
            self.CB_month.set(self._date.month)
            self._update()

        def _update(self, event = None, key = None):
            "" "refresh interface" ""
            if key and event.keysym != 'Return': return
            year = int(self.CB_year.get())
            month = int(self.CB_month.get())
            hour = int(self.CB_hour.get())
            mins = int(self.CB_mins.get())
            seconds = int(self.CB_seconds.get())
            if year == 0 or year > 9999: return
            self._canvas.place_forget()
            self._date = datetime(year, month,
1,hour,mins,seconds)
            self._build_calendar()#Rebuild calendar
            if year == datetime.now().year and month
== datetime.now().month:
                day = datetime.now().day
                for _item, day_list in
enumerate(self._cal.monthdayscalendar(year,
month)):
                    if day in day_list:
                        item = 'I00' + str(_item + 2)
                        column = '#' +
str(day_list.index(day)+1)
                        self.master.after(100,
lambda :self._pressed(item = item, column = column,
widget = self._calendar))
```

```
    def _exit(self, confirm = False):
        if not confirm: self._selection = None
        self.master.destroy()

    def _main_judge(self):
        "" "determine whether the window is at the
top level" ""
        try:
            if self.master.focus_displayof() ==
None or 'toplevel' not in
str(self.master.focus_displayof()): self._exit()
            else: self.master.after(10,
self._main_judge)
        except:
            self.master.after(10, self._main_judge)

    def selection(self):
        "" "returns the date time that represents the
currently selected date." ""
        if not self._selection:
            return None
        year, month = self._date.year,
self._date.month
        hour=self._date.hour
        mins = self._date.minute
        seconds = self._date.second
        return str(datetime(year, month,
int(self._selection[0]),hour,mins,seconds))

    def Input_judgment(self, content):
        "" "input judgment" ""
        if content.isdigit() or content == "":
            return True
        else:
            return False
```

1.7.2 Circular Queue Queue.py

```
class Queue:
    def __init__(self, limit=10):
        self.data = [None] * limit
        self.head = -1
        self.tail = -1

    def full(self):
        if (self.head+1)%len(self.data)==self.tail:
            return True
        else:
            return False

    def enqueue(self, val): # O(1)
        if self.empty():
            self.head=0
            self.tail=0
            self.data[0]=val
        else:
            if
(self.head+1)%len(self.data)==self.tail:
                raise RuntimeError()
            else:
                self.head= (self.head + 1) %
len(self.data)
                self.data[self.head] = val

    def peek(self):
        return self.data[self.head]

    def dequeue(self): # O(1)
        if self.empty():
            raise RuntimeError()
        ret = self.data[self.tail]
        self.data[self.tail] = None
        self.tail = (self.tail + 1) % len(self.data)
        if (self.head+1)%len(self.data)==self.tail:
            self.tail=self.head=-1
        return ret

    def resize(self, newsize):
        assert(len(self.data) < newsize)
        newq=Queue(newsize)
        for i in self:
```

```
            newq.enqueue(i)
        self.data=newq.data
        self.head=newq.head
        self.tail=newq.tail

    def empty(self):
        if self.head==self.tail==-1:
            return True
        return False

    def __bool__(self):
        return not self.empty()

    def __str__(self):
        if not(self):
            return ''
        return ', '.join(str(x) for x in self)

    def __repr__(self):
        return str(self)

    def __iter__(self):

head=(self.head+len(self.data))%len(self.data)
        tail=(self.tail+len(self.data))%len(self.data)
        i=tail
        while (i!=head):
            yield self.data[i]
            i=(i+1)%len(self.data)
        else:
            yield (self.data)
```

1.7.3 GUI and Main T1_main.py

```
import tkinter as tk
from tkinter import StringVar, ttk
from Calendar import Calendar
from Queue import Queue
from datetime import datetime as dt
from datetime import timedelta as td
import random as rd



class Vehicle():
    def __init__(self, number,arriveTime,
checkTime):
        self.number = number
        self.arriveTime = arriveTime
        self.checkTime = checkTime
        self.getinTime = None
        self.leaveTime = None

    def countWaitTime(self):
        return
self.leaveTime-self.arriveTime-self.checkTime

    def countThouTime(self):
        return self.leaveTime-self.arriveTime


def GUI():
    def getdate(type):
        for date in [Calendar().selection()]:
            if date:
                if(type == 'start'):    #If it is a start
button, assign it to the start date
start_date.set(date)
                elif(type == 'end'):
                    end_date.set(date)



    def cmd():
        a=int(entry3.get())
        b=int(entry4.get())
        c=int(entry5.get())
        d=int(entry6.get())
```

```
        k=int(entry7.get())
        start=dt.strptime(start_date.get(),
"%Y-%m-%d %H:%M:%S")
        end=dt.strptime(end_date.get(),
"%Y-%m-%d %H:%M:%S")
        currentTime=start

        vehicles =
[Vehicle(0,start+td(minutes=rd.randint(a, b)),

checkTime=td(minutes=rd.randint(c, d)))]
        n = int((end-start).total_seconds()//60//a)
        for i in range(1, n):

vehicles.append(Vehicle(i,vehicles[i-1].arriveTime+td
(minutes=rd.randint(a, b)), td(minutes=rd.randint(c,
d))))

        waitQueue = Queue(limit=n)
        checkQueue = Queue(limit=k)

        i=0
        l=0
        while (currentTime <= end):
            if
vehicles[i].arriveTime<=currentTime:
                waitQueue.enqueue(vehicles[i])

vehicles[i].arriveTime=currentTime
                i+=1
                print(currentTime)

print("Event:","Vehicle",vehicles[i].number,"arrive at
the custom")

            if (not checkQueue.full()) and (not
waitQueue.empty()):
                tmp=waitQueue.dequeue()
                checkQueue.enqueue(tmp)
                tmp.getinTime = currentTime
            if not checkQueue.empty():
                if checkQueue.peek().getinTime +
checkQueue.peek().checkTime>=currentTime:
                    tmp=checkQueue.dequeue()
vehicles[i].leaveTime=currentTime
                    l+=1
                    print(currentTime)

print("Event:","Vehicle",tmp.number,"leave the
custom")
            currentTime+=td(minutes=1)

        avgeWaitTime=td()
        avgeThouTime=td()
        for j in range(l):

avgeWaitTime+=vehicles[i].countWaitTime()

avgeThouTime+=vehicles[i].countThouTime()

        print("Average Wait
Time:",-avgeWaitTime/l)
        print("Average Through
Time:",-avgeThouTime/l)




    root = tk.Tk()
    root.title('Customs Checkpoint Simulation
System')
    root.geometry('300x300')
    root.resizable(False,False)
    start_date=tk.StringVar()
    end_date=tk.StringVar()
    button1=tk.Button(root,
                      width=15,
                      text='Start Date',
                      command=lambda:
getdate('start'))
    button1.place(x=20,
                  y=10,
                  width=100,
                  height=30)
    entry1=tk.Entry(root, textvariable=start_date)
    entry1.place(x=150,
                 y=10,
```

```
                    width=125,
                    height=30)
    button2=tk.Button(root, width=15, text='End
Date', command=lambda: getdate(
          'end'))
    button2.place(x=20,
                    y=70,
                    width=100,
                    height=30)
    entry2=tk.Entry(root,textvariable=end_date)
    entry2.place(x=150,
                    y=70,
                    width=125,
                    height=30)


button3=tk.Button(root,text="Confirm",command =
cmd)

    entry3=tk.Entry(root,width=5)
    entry4=tk.Entry(root,width=5)
    entry5=tk.Entry(root,width=5)
    entry6=tk.Entry(root,width=5)
    entry7=tk.Entry(root,width=5)

    label1=tk.Label(root,text='a=')
    label2=tk.Label(root,text='b=')
    label3=tk.Label(root,text='c=')
    label4=tk.Label(root,text='d=')
    label5=tk.Label(root,text='k=')

    entry3.place(x=80,
                    y=130,
                    width=30,
                    height=30)
    label1.place(x=40,
                    y=130,
                    width=30,
                    height=30)

    entry4.place(x=80,
                    y=190,
                    width=30,
                    height=30)
label2.place(x=40,
                    y=190,
                    width=30,
                    height=30)

entry5.place(x=200,
                    y=130,
                    width=30,
                    height=30)
label3.place(x=160,
                    y=130,
                    width=30,
                    height=30)

entry6.place(x=200,
                    y=190,
                    width=30,
                    height=30)
label4.place(x=160,
                    y=190,
                    width=30,
                    height=30)

entry7.place(x=80,
                    y=250,
                    width=30,
                    height=30)
label5.place(x=40,
                    y=250,
                    width=30,
                    height=30)

button3.place(x=150,
                    y=250,
                    width=100,
                    height=30)
root.mainloop()

GUI()
```

2. Calculate the truth value of propositional calculus formulas

2.1 Calculate the truth value of propositional calculus formulas

【Problem Description】

The propositional calculus formula refers to a formula composed of logical variables (its value is TRUE or FALSE) and logical operators ∧ (AND), ∨ (OR) and (NOT) according to certain rules (operations such as implication can be used ∧ , ∨ and to represent). The sequence of formula operations is ! , ∧, ∨, and parentheses () can change the priority. Given a propositional calculus formula and the value of each variable, it is required to design a program to calculate the truth value of the formula.

【Basic Requirements】

(1) Use a binary tree to calculate the truth value of the formula.
Firstly, use the stack to change the infix form of the formula into the suffix form. Secondly, according to the suffix form, construct the corresponding binary tree from the leaf node. Finally, traverse the binary tree in post-order, and find the value of each subtree. That is, each time a node is reached, the value of its subtree has been calculated. When the root node is reached, the truth value of the formula is obtained.
(2) Design a variety of propositional calculus formulas in different forms, and check the validity of each propositional calculus formula.
(3) The identifier of the logical argument is not limited to a single letter, but can be an alphanumeric string of any length. Logical arguments can appear multiple times in a formula.
(4) Print the construction process of the binary tree, print suffix form of the formula and the post-order traversal sequence of the binary tree.
(5) Enter the value of each variable, calculate and display the truth value of the formula, print the evaluation process of the binary tree.
(6) Display the truth table of the formula.

【Extension Requirements】

Please replace logical operators with arithmetic operators and use binary tree to calculate the arithmetic expression.

2.2 Requirement Analysis

2.2.1 Input

Enter the propositional calculus formula.

2.2.2 Function

(1) Test the legitimacy of propositional calculus formula.
(2) Convert propositional calculus formula into suffix expression.
(3) Convert the suffix expression into an expression tree and print its construction process.
(4) Using the expression tree to calculate the truth value of the propositional calculus formula, and print its truth table.

2.2.3 Output

Output the suffix expression of propositional calculus formula, the construction process of expression tree, and the truth table of propositional calculus formula.

2.3 Design

2.3.1 Design Idea

2.3.1.1 Data Structure Design

2.3.1.1.1 Logical Structure Design

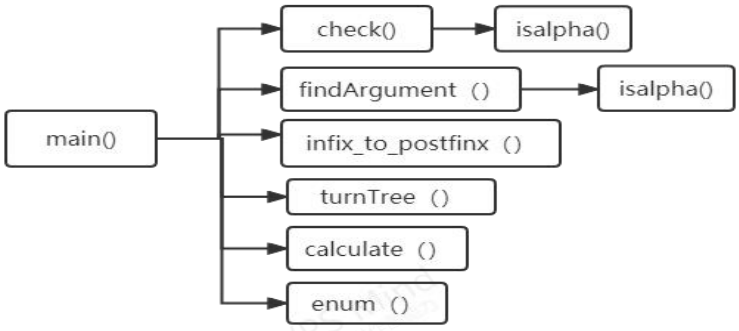
2.3.1.1.2 Storage Structure Design

1. Use the dictionary to store the priority of operators, which is convenient for looking up the dictionary when using.
2. Use a binary tree to store the expression tree.
3. Use the stack to build suffix expressions and expression trees.

2.3.1.2 Algorithm Design

(1) Stack is used to check the validity of propositional formula.
(2) Linear search is used to distinguish propositional arguments from operators.
(3) Use stack to convert infix expression into suffix expression.
(4) Use stack to transform suffix expression into expression tree.
(5) Using binary tree to recursively calculate the truth value of a proposition.
All interpretations of propositional formulas are generated by binary transformation.

2.3.2 Design Representation



2.3.3 Detailed Design

2.3.3.1 Test the Legitimacy of Propositional Formula

```
#Distinguishing propositional arguments from truth values
def isalpha(word):
    If ('!','∧','∨','(',')',' ') is in word
        return False
    else
        return True

#Check legitimacy
def check(expr):
    s = Stack()
#Check the legitimacy of the beginning and end of the propositional formula
    if expr begins with ['∧','∨'] or ends with ['∧','∨','!']
        return False
    else:
#Illegal enumeration operator
        if expr[i] in ['∧','∨'] and expr[i+1] in ['∧','∨',')']
            return False
        elif expr[i] in ['!','('] and expr[i+1] in ['∧','∨',')']:
            return False
        elif expr[i]=='(':expr[i+1] in ['∧','∨']:
            return False
        elif expr[i]==')' and expr[i+1]=='!':
            return False
#Check the validity of brackets
        if expr[i] == '(':
            s.push(expr[i])
```

```
        elif expr[i] == ')':
            if s.empty():
                return False
            elif s.pop() != '(':
                return False
    return s.empty()
```

2.3.3.2 Infix Expression Converted to Postfix Expression

(1) Create a stack and a linear table.

(2) Traversing infix, the array elements are propositional arguments and directly enter the linear table; The array elements are operators and (), advanced stack.

a. When entering the stack, the priority of the top element is obtained first. If the priority of this element is greater than or equal to the top element, the top element pops up and is stored in the linear table.

b. If the element is "(", it is directly put on the stack.

c. If the stack is empty or the element at the top of the stack is "(", it will be directly put on the stack.

d. If the element is ")" the element in the stack pops up and is stored in the linear table until the element at the top of the stack is "(".

(4) Pop up the remaining elements in the stack in turn and put them into the linear table.

```
def infix_to_postfix(expr):
    ops = Stack()
    postfix = []
    toks = expr.split()
#Handling parentheses
    for c in toks:
        if c == '(':
            ops.push(c)。
        elif c == ')':
            while ops.peek() != '(':
                postfix.append(ops.pop())
            ops.pop()
#Dealing with propositional arguments
        elif isalpha(c):
            postfix.append(c)
        else:
#Push by operator priority
            while bool(ops) and prec[ops.peek()] >= prec[c]:
                postfix.append(ops.pop())
            ops.push(c)
#Pop the remaining operators out of the stack
    while bool(ops):
        postfix.append(ops.pop())
    return postfix
```

2.3.3.3 Convert Postfix Expression to Expression Tree

(1) Create a stack and prepare each symbol of the suffix expression to be pushed into the stack.

(2) If the symbol is a number, the number represents a single node tree and is pushed onto the stack.

(3) If the symbol is a binary operator, pop out two elements from the stack at a time, the first is the right subtree, the second is the left subtree, and then push the newly generated tree onto the stack.

(4) If the symbol is a unary operator, pop out one element as a right subtree from the stack at a time, and then push the newly generated tree onto the stack.

(5) Finally, there is only one tree node element left in the stack. Pop it out and it is the root node of the expression tree.

```
def turnTree(postfix):
    s=Stack()
    for i in postfix:
        if isalpha(i):
            s.push(BTree.Node(i))
        elif i=='!':
            a=s.pop()
            tmp=BTree.Node(i,left=None,right=a)
            BTree.pprint(tmp)
            s.push(tmp)
        elif i in ['∧','∨']:
            a=s.pop()
            b=s.pop()
            tmp=BTree.Node(i,left=b,right=a)
            BTree.pprint(tmp)
            s.push(tmp)
    t=BTree()
    t.root=s.pop()
    return t
```

2.3.3.4 Calculate the Expression Tree

(1) Traverse the expression tree from the root node.
(2) If the node value is an operator, recursively call the calculate function to calculate the value of this node as the root node.
(3) If the node value is a propositional argument, return its true value.

```
def calculate(node):
    if node:
        if node.val not in ('∧','∨','!'):
            return values[node.val]
        elif node.val =='!':
            return not calculate(node.left)
        elif node.val == '∧':
            return calculate(node.left) and calculate(node.right)
        elif node.val == '∨':
            return calculate(node.left) or calculate(node.right)
```

2.3.3.5 Find all non repeating propositional arguments in propositional formulas

（1）Traverse the propositional formula. If it is not an operator, it will be added to the list of propositional arguments.

```
def findArgument(expr):
    arguments=[]
    temp=expr.split()
    for i in temp:
        if i not in    ('!','∧','∨','(',')',' '):
            arguments.append(i)
    return arguments
```

2.3.3.6 Enumerate all truth values of propositional arguments

(1) Traversal interval [0,2^n], n is the number of proposition arguments.
(2) Convert I into binary, and then convert it into a string, with a supplementary leading '0' of less than n bits.
(3) Convert each STR into decimal system, corresponding to the truth value of the nth proposition argument, and add it to the truth dictionary.
(4) Each time the loop is executed, the truth dictionary is added to the list of truth dictionaries.

```
def enum(arguements):
    lst=[]
    for i in range(2**len(arguments)):
        dic={}
        s=str(bin(i))[2::]
        if len(s)<len(arguments):
            s='0'*(len(arguments)-len(s))+s
        s=[int (k) for k in s]
        for j in range(len(arguments)):
            dic[arguments[j]]=s[j]
        lst.append(dic)
    return lst
```

2.3.3.7 Visualization of the Binary Tree

```
import networkx as nx
import matplotlib.pyplot as plt
#Recursively traverse the binary tree and calculate the seat of each node
def create_graph(G, node, pos={}, x=0, y=0, layer=1):
    pos[node.val] = (x, y)
    if node.left:
        G.add_edge(node.val, node.left.val)
        l_x, l_y = x - 1 / 2 ** layer, y - 1
        l_layer = layer + 1
        create_graph(G, node.left, x=l_x, y=l_y, pos=pos, layer=l_layer)
    if node.right:
        G.add_edge(node.val, node.right.val)
        r_x, r_y = x + 1 / 2 ** layer, y - 1
        r_layer = layer + 1
        create_graph(G, node.right, x=r_x, y=r_y, pos=pos, layer=r_layer)
```

```
    return (G, pos)

def draw(node):


#Draw a graph with a node as the root
    graph = nx.DiGraph()
    graph, pos = create_graph(graph, node)
    fig, ax = plt.subplots(figsize=(8, 10))
    nx.draw_networkx(graph, pos, ax=ax,
node_size=1000)
    plt.show()
```

2.3.3.8 Expansion requirements - calculate the value of arithmetic expression

```
from Stack import Stack
import BTreeVisualization as BTV
from BTree import BTree

prec = {'*': 2,'/': 2, '+': 1,'-':1,'(': 0, ')': 0}

def infix_to_postfix(expr):
    ops = Stack()
    postfix = []
    toks = expr.split()

    for c in toks:
        if c == '(':
            ops.push(c)
        elif c == ')':
            while ops.peek() != '(':
                postfix.append(ops.pop())
            ops.pop()
        elif c.isdigit():
            postfix.append(c)
        else:
            while bool(ops) and
prec[ops.peek()] >= prec[c]:
                postfix.append(ops.pop())
            ops.push(c)
    while bool(ops):
        postfix.append(ops.pop())
    return postfix

def turnTree(postfix):
    s=Stack()
    for i in postfix:
        if i.isdigit():
            s.push(BTree.Node(i))
        elif i in ['+','-','/','*']:
            a=s.pop()
            b=s.pop()

tmp=BTree.Node(i,left=b,right=a)
            BTree.pprint(tmp)
            s.push(tmp)

    t=BTree()
    t.root=s.pop()
    return t

def calculate(node):
    if node:
        if node.val not in ('+','-','*','/'):
            return int(node.val)
        elif node.val =='+':
            return calculate(node.left) +
calculate(node.right)
        elif node.val == '-':
            return calculate(node.left) -
calculate(node.right)
        elif node.val == '*':
            return calculate(node.left) *
calculate(node.right)
        elif node.val == '/':
            return calculate(node.left) /
calculate(node.right)
```

```
                                        print(a)
a=input()                               a=turnTree(a)
a=infix_to_postfix(a)                   print(calculate(a.root))
```

2.4 Debugging analysis

2.4.1 Problems encountered and Solutions

Problem encountered: when constructing the expression tree, the sequence of arguments of binary operator proposition is inverted.
Solution: when constructing the expression tree with the help of stack, take the proposition argument of pop first as the right node, and the proposition argument of pop later as the left node。

2.4.2 Time and Space Complexity

Time complexity: O (n)
Space complexity: O (n)

2.5 User 's Manual

2.5.1 Input

Enter a propositional formula, and the arguments and operators of each proposition are separated by spaces. If the formula is illegal, re-enter it according to the prompt.

2.5.2 Output

Output the postfix expression (post order traversal of binary tree), the construction process of expression tree, expression tree, and the truth table of expression tree in turn.

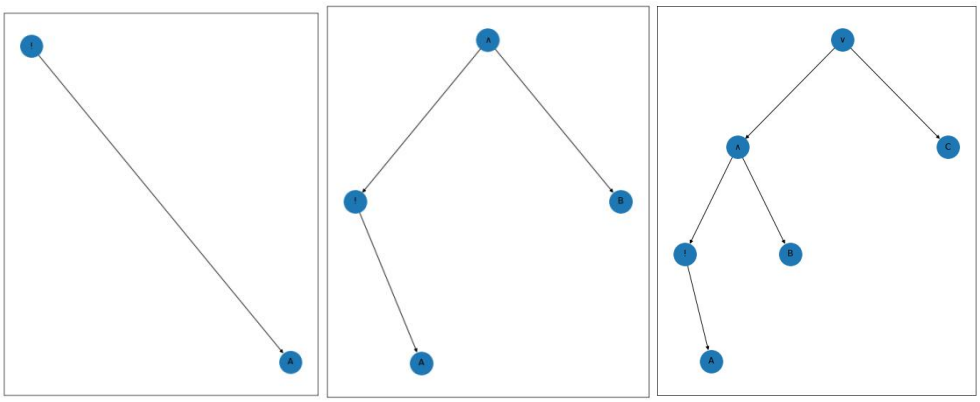
2.6 Test Data and Test Results

Test Case 1

Test Input	∧ (! A ∧ B) ∨ C

Test Purpose	Function of checking the validity of formulas
Correct Output	Retry!
Actual Output	Retry!
Cause of error	
current state	Passed

Test Case 2

Test Input	(! A ∧ B) ∨ C
Test Purpose	Check the function of infix expression to suffix expression, and check the function of establishing expression tree and visualization
Correct Output	A ! B ∧ C ∨
Actual Output	A ! B ∧ C ∨ 
Cause of error	
current state	Passed

Test Case 3

Test Input	(! A ∧ B) ∨ A ∧ C
Test Purpose	The function of checking and judging the number of arguments of propositions and printing the truth table.
Correct Output	{'A': 0, 'B': 0, 'C': 0} 0 {'A': 0, 'B': 0, 'C': 1} 0 {'A': 1, 'B': 0, 'C': 0} 0 {'A': 1, 'B': 0, 'C': 1} 1

	{'A': 0, 'B': 1, 'C': 0} 0 {'A': 1, 'B': 1, 'C': 0} 0 {'A': 0, 'B': 0, 'C': 0} 0 {'A': 1, 'B': 0, 'C': 0} 0 {'A': 0, 'B': 1, 'C': 0} 0 {'A': 1, 'B': 1, 'C': 0} 0	{'A': 0, 'B': 1, 'C': 1} 1 {'A': 1, 'B': 1, 'C': 1} 1 {'A': 0, 'B': 0, 'C': 1} 0 {'A': 1, 'B': 0, 'C': 1} 1 {'A': 0, 'B': 1, 'C': 1} 1 {'A': 1, 'B': 1, 'C': 1} 1
Actual Output	{'A': 0, 'B': 0, 'C': 0} 0 {'A': 1, 'B': 0, 'C': 0} 0 {'A': 0, 'B': 1, 'C': 0} 0 {'A': 1, 'B': 1, 'C': 0} 0 {'A': 0, 'B': 0, 'C': 0} 0 {'A': 1, 'B': 0, 'C': 0} 0 {'A': 0, 'B': 1, 'C': 0} 0 {'A': 1, 'B': 1, 'C': 0} 0	{'A': 0, 'B': 0, 'C': 1} 0 {'A': 1, 'B': 0, 'C': 1} 1 {'A': 0, 'B': 1, 'C': 1} 1 {'A': 1, 'B': 1, 'C': 1} 1 {'A': 0, 'B': 0, 'C': 1} 0 {'A': 1, 'B': 0, 'C': 1} 1 {'A': 0, 'B': 1, 'C': 1} 1 {'A': 1, 'B': 1, 'C': 1} 1
Cause of error		
current state	Passed	

2.7 Source Program List

2.7.1 Implementation of Simple Stack Stack.py

```
class Stack:
    def __init__(self):
        self.data = []

    def push(self, val):
        self.data.append(val)

    def pop(self):
        assert not self.empty()
        ret = self.data[-1]
        del self.data[-1]
        return ret

    def peek(self):
        assert not self.empty()
        return self.data[-1]

    def empty(self):
        return len(self.data) == 0

    def __bool__(self):
        return not self.empty()
```

2.7.2 Implementation of Binary Tree BTree.py

```
import networkx as nx
import matplotlib.pyplot as plt


class BTree:
    class Node:
        def __init__(self, val, left=None, right=None):
            self.val = val
            self.left = left
            self.right = right

    def __iter__(self):
        def iter_rec(n):
            if n:
                yield from iter_rec(n.left)
                yield from iter_rec(n.right)
                yield n
        return iter_rec(self.root)


    def __init__(self):
        self.root = None

    def height(node):
        def height_rec(t):
            if not t:
                return 0
            else:
                return 1 + max(height_rec(t.left), height_rec(t.right))
        return height_rec(node)

    def pprint(node,width=128):
        height = BTree.height(node)
        nodes  = [(node, 0)]
        prev_level = 0
        repr_str = ''
        while nodes:
            n,level = nodes.pop(0)
            if prev_level != level:
                prev_level = level
                repr_str += '\n'
            if not n:
                if level < height-1:
                    nodes.extend([(None, level+1), (None, level+1)])
                repr_str += '{val:^{width}}'.format(val='-', width=width//2**level)
            elif n:
                if n.left or level < height-1:
                    nodes.append((n.left, level+1))
                if n.right or level < height-1:
                    nodes.append((n.right, level+1))
                repr_str += '{val:^{width}}'.format(val=n.val, width=width//2**level)
        print(repr_str)
        print('-'*128)
```

2.7.3 Binary Tree Visualization BtreeVisualization.py

```
import networkx as nx
import matplotlib.pyplot as plt

def create_graph(G, node, pos={}, x=0, y=0, layer=1):
    pos[node.val] = (x, y)
    if node.left:
        G.add_edge(node.val, node.left.val)
        l_x, l_y = x - 1 / 2 ** layer, y - 1
        l_layer = layer + 1
        create_graph(G, node.left, x=l_x, y=l_y, pos=pos, layer=l_layer)
    if node.right:
        G.add_edge(node.val, node.right.val)
        r_x, r_y = x + 1 / 2 ** layer, y - 1
```

```
        r_layer = layer + 1
        create_graph(G, node.right, x=r_x,
y=r_y, pos=pos, layer=r_layer)
    return (G, pos)

def draw(node):
    graph = nx.DiGraph()
    graph, pos = create_graph(graph, node)
    fig, ax = plt.subplots(figsize=(8, 10))
    nx.draw_networkx(graph, pos, ax=ax,
node_size=1000)
    plt.show()
```

2.7.4 main T2_main.py

```
from Stack import Stack
import BTreeVisualization as BTV
from BTree import BTree

def isalpha(word):
    for i in ('!','∧','∨','(',')',' '):
        if i in word:
            return False
    return True

def findArgument(expr):
    arguments=[]
    temp=expr.split()
    for i in temp:
        if i not in    ('!','∧','∨','(',')',' '):
            arguments.append(i)
    return arguments

def check(expr):
    s = Stack()
    expr=expr
    if expr[0] in ['∧','∨']:
        return False
    elif (expr[-1] in ['∧','∨','!']):
        return False
    else:
        for i in range(len(expr)):
            if i<len(expr)-1:
                if expr[i] in ['∧','∨']:
                    if  expr[i+1]  in  [' ∧ ','
∨',')']:
                        return False
                elif expr[i]=='!':
                    if  expr[i+1]  in  [' ∧ ','
∨',')']:
                        return False
                elif expr[i]=='(':
                    if  expr[i+1]  in  [' ∧ ','
∨']:
                        return False
                elif expr[i]==')':
                    if expr[i+1]=='!':
                        return False

            if expr[i] == '(':
                s.push(expr[i])
            elif expr[i] == ')':
                if s.empty():
                    return False
                elif s.pop() != '(':
                    return False

    return s.empty()

prec = {'!': 2,'∧': 1, '∨': 1,'(': 0, ')': 0}

def infix_to_postfix(expr):
    ops = Stack()
    postfix = []
    toks = expr.split()

    for c in toks:
        if c == '(':
            ops.push(c)
        elif c == ')':
            while ops.peek() != '(':
                postfix.append(ops.pop())
            ops.pop()
```

```
            elif isalpha(c):
                postfix.append(c)
            else:
                while bool(ops) and prec[ops.peek()] >= prec[c]:
                    postfix.append(ops.pop())
                ops.push(c)
        while bool(ops):
            postfix.append(ops.pop())
        return postfix

def turnTree(postfix):
        s=Stack()
        for i in postfix:
            if isalpha(i):
                s.push(BTree.Node(i))
            elif i=='!':
                a=s.pop()

tmp=BTree.Node(i,left=None,right=a)
                BTree.pprint(tmp)
                s.push(tmp)
            elif i in ['∧','∨']:
                a=s.pop()
                b=s.pop()

tmp=BTree.Node(i,left=b,right=a)
                BTree.pprint(tmp)
                s.push(tmp)

        t=BTree()
        t.root=s.pop()
        return t

def calculate(node):
        if node:
            if node.val not in ('∧','∨','!'):
                return values[node.val]
            elif node.val =='!':
                return not calculate(node.left)
            elif node.val == '∧':
                return calculate(node.left) and calculate(node.right)
            elif node.val == '∨':
                return calculate(node.left) or calculate(node.right)

def enum(arguements):
        lst=[]
        for i in range(2**len(arguments)):
            dic={}
            s=str(bin(i))[2::]
            if len(s)<len(arguments):
                s='0'*(len(arguments)-len(s))+s
            s=[int (k) for k in s]
            for j in range(len(arguments)):
                dic[arguments[j]]=s[j]
            lst.append(dic)
        return lst

print("请输入命题公式 示例:(！A ∧ B) ∨ C")
expr=input()
values=None
legal=check(expr)
while not legal:
        print("Retry!")
        expr=input()
        legal=check(expr)
else:
        arguments=findArgument(expr)
        expr1=infix_to_postfix(expr)
        t=turnTree(expr1)
        explain=enum(arguments)
        BTree.pprint(t.root)

        for i in range(2**len(arguments)):
            values=explain[i]
            print(explain[i],calculate(t.root))
```

2.7.5 Expansion requirements main

T2_ExtendedRequirements.py

```
from Stack import Stack
import BTreeVisualization as BTV
from BTree import BTree

prec = {'*': 2,'/': 2, '+': 1,'-':1,'(': 0, ')': 0}

def infix_to_postfix(expr):
    ops = Stack()
    postfix = []
    toks = expr.split()

    for c in toks:
        if c == '(':
            ops.push(c)
        elif c == ')':
            while ops.peek() != '(':
                postfix.append(ops.pop())
            ops.pop()
        elif c.isdigit():
            postfix.append(c)
        else:
            while bool(ops) and prec[ops.peek()] >= prec[c]:
                postfix.append(ops.pop())
            ops.push(c)
    while bool(ops):
        postfix.append(ops.pop())
    return postfix

def turnTree(postfix):
    s=Stack()
    for i in postfix:
        if i.isdigit():
            s.push(BTree.Node(i))
        elif i in ['+','-','/','*']:
            a=s.pop()
            b=s.pop()

tmp=BTree.Node(i,left=b,right=a)
            BTree.pprint(tmp)
            s.push(tmp)

    t=BTree()
    t.root=s.pop()
    return t

def calculate(node):
    if node:
        if node.val not in ('+','-','*','/'):
            return int(node.val)
        elif node.val =='+':
            return calculate(node.left) + calculate(node.right)
        elif node.val == '-':
            return calculate(node.left) - calculate(node.right)
        elif node.val == '*':
            return calculate(node.left) * calculate(node.right)
        elif node.val == '/':
            return calculate(node.left) / calculate(node.right)

a=input()
a=infix_to_postfix(a)
print(a)
a=turnTree(a)
print(calculate(a.root))
```