Project documentation

Data structure course design

——Course scheduling software

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1. Analysis

1.1 Project background analysis

Courses are arranged for each major at the university. Assume that any major has a fixed period of study. Each academic year contains two semesters. The courses offered by each major are determined, and the schedule of the courses must meet the prerequisite relationship. The prerequisites for each course are determined. Each course takes exactly one semester, assuming that there are five lessons each morning and afternoon. It is on this premise to design a teaching plan preparation process.

1.2 Project function requirements

1. The input data includes: the number of courses offered per semester (the sum of the number of courses offered per semester must be equal to the total number of courses), the course number, the course name, the number of weekly hours, the designated start semester, the prerequisites If the designated start semester is 0, it means that there is a computer to designate the start semester.
2. If the input data is not reasonable, such as the number of courses offered each semester and the total number of courses are not equal, appropriate prompt information should be displayed.
3. Store the input data in a text file and load it into the computer.
4. Use text files to store the lesson schedules for each semester.

Schedule requirements and course information:

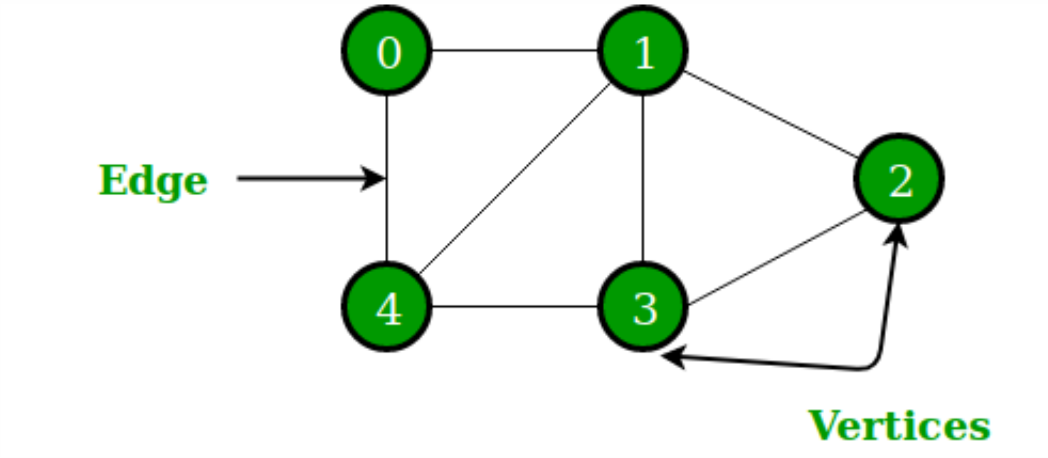
Assume that there are classes from Monday to Friday. There are 10 lessons per day. The first major session is 1-2. The second major session is 3-5. The third major session is 6-7. The 4 major sections are 8-10 lessons. When arranging lessons, if there are 3 lessons in a course, 3 consecutive lessons will be given priority; if 3 consecutive lessons cannot be arranged, then 2 lessons will be given consecutively. Reschedule a single lesson; if a course needs to be scheduled for two days, for better teaching results, it is best not to arrange for two consecutive days, such as giving priority to two lessons apart, and set weekday to indicate that the current schedule Working day, the working day of the next scheduled class is:

$weekday = (weekday + 2 - 5)?(Weekday + 2 - 5) : (weekday + 2);$

2. Design

2.1 Data structure design

The schedual is a typical graph data structure,whiche consists of a finite set of vertices(or nodes) and set of Edges which connect a pair of nodes.The above sentence is the definition of the graph,A Graph is a non-linear data structure consisting of nodes and edges. The nodes are sometimes also referred to as vertices and the edges are lines or arcs that connect any two nodes in the graph.



In the above Graph, the set of vertices $V = 0, 1, 2, 3, 4$ and the set of edges$E = 01, 12, 23, 34, 04, 14, 13$.

Graphs are used to solve many real-life problems. Graphs are used to represent networks. The networks may include paths in a city or telephone network or circuit network. Graphs are also used in social networks like linkedIn, Facebook. For example, in Facebook, each person is represented with a vertex(or node). Each node is a structure and contains information like person id, name, gender, locale etc.

The "create grid vertex" function of this question corresponds to the point of creating a graph structure and determining the size of the graph. The corresponding operation of "adding the edge of the grid" is to construct the edges of the graph. For the convenience of coding this question and the subsequent implementation of the minimum spanning tree, this question uses a storage structure called adjacency matrix to store graph structure.

Graph is a data structure that consists of following two components: **1.** A finite set of vertices also called as nodes. **2.** A finite set of ordered pair of the form (u, v) called as edge. The pair is ordered because (u, v) is not same as (v, u) in case of a directed graph(di-graph). The pair of the form (u, v) indicates that there is an edge from vertex u to vertex v. The edges may contain weight/value/cost.

Now let's analyze the five-vertex graph in the previous figure :

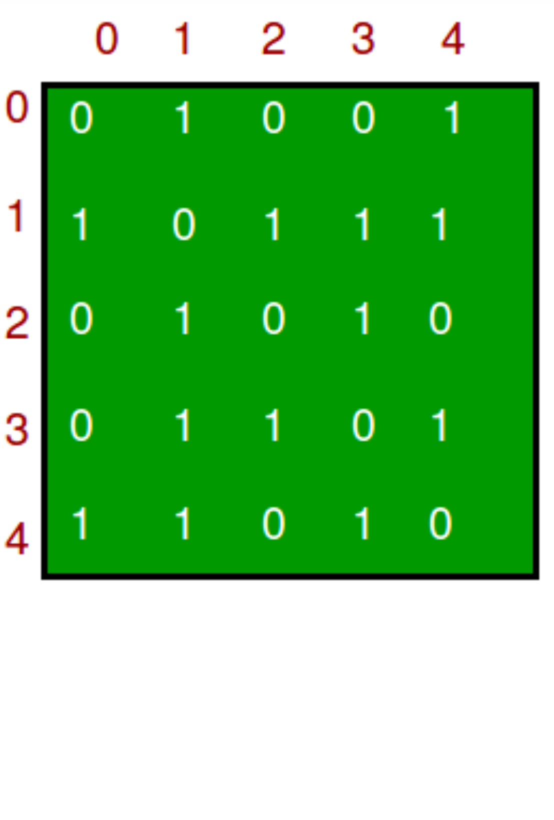
Following two are the most commonly used representations of a graph.

1. Adjacency Matrix
2. Adjacency List

There are other representations also like, Incidence Matrix and Incidence List. The choice of the graph representation is situation specific. It totally depends on the type of operations to be performed and ease of use.

Adjacency Matrix: Adjacency Matrix is a 2D array of size $V \times V$ where V is the number of vertices in a graph. Let the 2D array be $adj[][]$, a slot $adj[i][j] = 1$ indicates that there is an edge from vertex i to vertex j. Adjacency matrix for undirected graph is always symmetric. Adjacency Matrix is also used to represent weighted graphs. If $adj[i][j] = w$, then there is an edge from vertex i to vertex j with weight w.

The adjacency matrix for the above example graph is:



> *Pros:* Representation is easier to implement and follow. Removing an edge takes $O(1)$ time. Queries like whether there is an edge from vertex 'u' to vertex 'v' are efficient and can be done $O(1)$.
>
> *Cons:* Consumes more space $O(V^2)$. Even if the graph is sparse(contains less number of edges), it consumes the same space. Adding a vertex is $O(V^2)$ time.

Adjacency List: An array of lists is used. Size of the array is equal to the number of vertices. Let the array be $array[]$. An entry $array[i]$ represents the list of vertices adjacent to the ith vertex. This representation can also be used to represent a weighted graph. The weights of edges can be represented as lists of pairs. Following is adjacency list representation of the above graph.

2.2 *Algorithm design*

The main algorithm involved in this problem is the **Topological sort** used to construct the minimum spanning tree.

Topological sorting for Directed Acyclic Graph (DAG) is a linear ordering of vertices such that for every directed edge uv, vertex u comes before v in the ordering. Topological Sorting for a graph is not possible if the graph is not a DAG.

For example, a topological sorting of the following graph is “5 4 2 3 1 0”. There can be more than one topological sorting for a graph. For example, another topological sorting of the following graph is “4 5 2 3 1 0”. The first vertex in topological sorting is always a vertex with in-degree as 0 (a vertex with no incoming edges).

Topological Sorting vs Depth First Traversal (DFS): In DFS, we print a vertex and then recursively call DFS for its adjacent vertices. In topological sorting, we need to print a vertex before its adjacent vertices. For example, in the given graph, the vertex ‘5’ should be printed before vertex ‘0’, but unlike DFS, the vertex ‘4’ should also be printed before vertex ‘0’. So Topological sorting is different from DFS. For example, a DFS of the shown graph is “5 2 3 1 0 4”, but it is not a topological sorting.

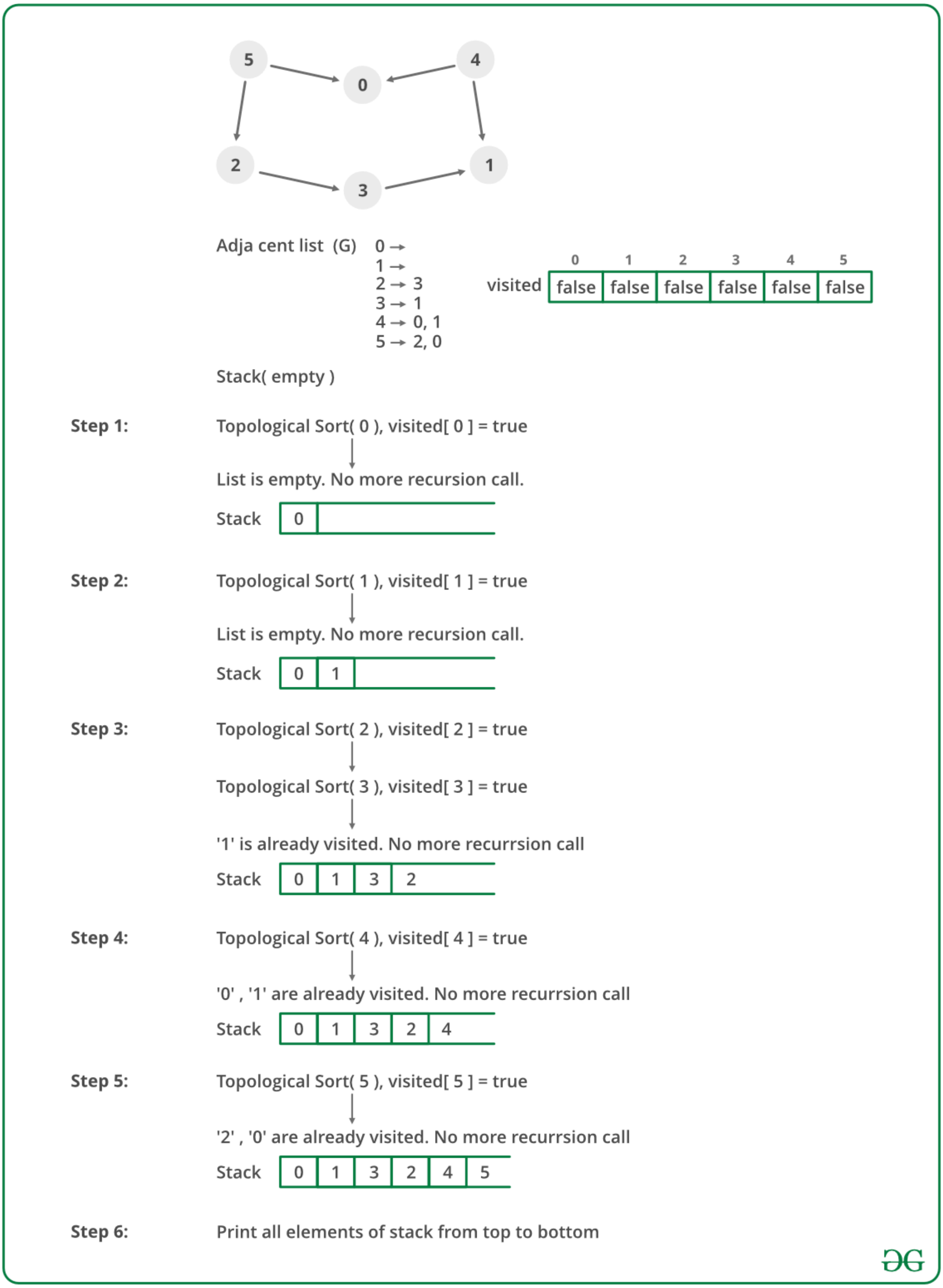
Algorithm to find Topological Sorting:

We recommend to first see implementation of DFS here. We can modify DFS to find Topological Sorting of a graph. In DFS , we start from a vertex, we first print it and then recursively call DFS for its adjacent vertices. In topological sorting, we use a temporary stack. We don’t print the vertex immediately, we first recursively call topological sorting for all its adjacent vertices, then push it to a stack. Finally, print contents of stack. Note that a vertex is pushed to stack only when all of its adjacent vertices (and their adjacent vertices and so on) are already in stack.

Simply put, the method of topological sorting can be summarized as:

1. Find points with a degree of 0 and put them into a sorted sequence
2. Delete all edges emitted by this point
3. Continue to find the next point with a degree of 0, put it into the sequence, and repeat the above steps
4. Until all nodes are put into the sequence.

Below image is an illustration of the above approach:



2.3 Member and operational design

1. Course

Private:

```
std::string _number;//课程编号
    std::string _name;//课程名字
    int _time;//学时数
    int _semester;//开课学期
    bool _havePre;
    int _degree;//入度
    std::vector<std::string> _pre;
```

Public operation:

```
Course() {
        _number = "0";
        _name = "0";
        _havePre = false;
        _degree = 0;

    }

    Course(std::string &nu, std::string &na, int ti, int se, bool ha) {
        _number = nu;
        _name = na;
        _time = ti;
        _semester = se;
        _havePre = ha;
    }
```

2. Graph

Data & functions:

```
public:
    std::vector<Course> _name;         //储存顶点名称的数组
    std::vector<Course> _classname;  //在矩阵中有用的顶点们
    int _matrix[29][29];       //邻接矩阵表示
    int _size;            //course name数
    int _vertexes;  //真实的顶点数
    std::vector<Course> _classlist;//拓扑排序后的课程顺序
    Graph() = default;

    Graph(std::vector<Course> course) {
        _name = course;
        _size = course.size();
        _vertexes = 0;
    }

    void initMatrix();
```

```
    bool findInDegree(Course co);//查找入度为0的顶点
    std::vector<Course> topologicalSort();
```

Core function:

Initialize adjacency matrix :

```
void Graph::initMatrix() {
    for (auto &i : _name) {
        if (!i._semester) {
            _classname.push_back(i);
        }
    }
    _vertexes = _classname.size();
    int mat[_vertexes][_vertexes];
    for (int i = 0; i < _vertexes; ++i) {
        for (int j = 0; j < _vertexes; ++j) {
            mat[i][j] = 0;
            if (_classname[j]._havePre) {
                //j的前驱是i, 也就是i的后继是j matrix[i][j]置1
                for (auto it = _classname[j]._pre.begin(); it !=
_classname[j]._pre.end(); ++it) {
                    if (*it == _classname[i]._number) {
                        mat[i][j] = 1;
                    }
                }
            }
        }
    }

    for (int i = 0; i < _vertexes; ++i) {
        for (int j = 0; j < _vertexes; ++j) {
            _matrix[i][j] = mat[i][j];
        }
    }
}
```

Find vertex's degree:

```
void Graph::findInDegree() {
    for (int i = 0; i < _classname.size(); ++i) {
        std::cout << _classname[i]._degree << " ";
        _inDegree.push_back(_classname[i]._degree);
        if (_inDegree[i] == 0) {
            stk.push(i);
        }

    }
}
```

```
std::vector<Course> Graph::topologicalSort() {
    std::vector<Course> ans;
    findInDegree();
    int v;//下标
    while (!stk.empty()){
        v = stk.top();
        stk.pop();
        for(int i = 0;i < _classname.size();++i){
            if(_matrix[v][i] == 1){
                _inDegree[i] --;
                if(_inDegree[i] == 0){
                    stk.push(i);
                }
            }
        }
        ans.push_back(_classname[v]);
    }
        _classlist = ans;
    for (auto it = ans.begin(); it != ans.end(); ++it) {
        std::cout << it->_name << ' ';
    }
    return ans;
}
```

3. Realization

3.1 Implementation of Reading files and processing data

1. Reading file core code

```
ector<Course> readFile() {
    ifstream ifs;//输入
    ofstream ofstream1;//输出
    ifs.open("../in.txt");
    if (ifs.fail()) {
        cerr << "Error opeing a file" << endl;
        ifs.close();
        exit(1);
    }
    auto line = new string[10000];
    int num = 0;
    while (ifs >> line[num]) {
        num++;
    }

    vector<Course> courses;
    int j = 0;
    for (int i = 5; i < num; ++i) {
        if (line[i][0] == 'c' && line[i + 1][0] != 'c') {
            //判断是否为课号
            Course co;
            j++;//新增一个课程
            co._number = line[i];
            co._name = line[i + 1];
            int ti = stoi(line[i + 2]);
            int se = stoi(line[i + 3]);
            co._time = ti;
            co._semester = se;
            co._degree = 0;
            int k = i + 4;
            int m = 0;
            while (line[k][0] == 'c' && line[k + 1][0] == 'c') {
                co._havePre = true;
                co._pre.push_back(line[k]);
                co._degree++;
                m++;
                k++;
            }
            courses.push_back(co);
        }
    }
```

```
    ifs.close();
    return courses;//size
}
```

2. Reading file diagram

input file:

in.txt

课程编号	课程名称	学时数	指定开课学期	先修课程
c01	程序设计基础	5	0	
c02	离散数学	6	0	c01
c03	数据结构算法	4	0	c01 c02
c04	汇编语言	5	0	c01
c05	算法设计	4	0	c03 c04
c06	计算机组成原理	6	0	
c07	微机原理	4	0	c03
c08	单片机应用	3	0	c03
c09	编译原理	5	0	c03
c10	操作系统原理	4	0	c03
c11	数据库原理	5	0	c03
c12	高等数学	6	0	
c13	线性代数	6	0	
c14	数值分析	6	0	c12
c15	普通物理	4	0	c12
c16	计算机文化	3	0	
c17	计算机系统结构	6	0	c06
c18	计算机网络	5	0	c03
c19	数据通信	6	0	
c20	面向对象程序设计	3	0	c01 c03
c21	Java	3	0	c01 c03
c22	C#.net	5	0	c01 c03
c23	PowerBuilder	5	0	c01 c03
c24	VC++	3	0	c01 c03
c25	ASP程序设计	5	0	c01 c03
c26	JSP程序设计	5	0	c01 c03
c27	VB.net	5	0	c01 c03
c28	Delphi	5	0	c01 c03
c29	C++Builder	5	0	c01 c03
c30	英语	5	1	
c31	英语	5	2	
c32	英语	5	3	
c33	英语	5	4	
c34	英语	5	5	
c35	英语	5	6	
c36	英语	5	7	
c37	英语	5	8	
c38	大学语文	3	1	

out put:

```
/Users/xuedixuedi/lxdThings/Code/github/Data-Structure-design/009/cmake-build-debug/009
c01 程序设计基础
c02 离散数学
c03 数据结构算法
c04 汇编语言
c05 算法设计
c06 计算机组成原理
c07 微机原理
c08 单片机应用
c09 编译原理
c10 操作系统原理
c11 数据库原理
c12 高等数学
c13 线性代数
c14 数值分析
c15 普通物理
c16 计算机文化
c17 计算机系统结构
c18 计算机网络
c19 数据通信
c20 面向对象程序设计
c21 Java
c22 C#.net
c23 PowerBuilder
c24 VC++
c25 ASP程序设计
c26 JSP程序设计
c27 VB.net
c28 Delphi
c29 C++Builder
c30 英语
c31 英语
c32 英语
c33 英语
c34 英语
c35 英语
c36 英语
c37 英语
c38 大学语文
```

3.2 Directed graph adjacency matrix construction

1. Adjacency matrix construction core code

```
void Graph::initMatrix() {
    for (auto &i : _name) {
        if (!i._semester) {
            _classname.push_back(i);
        }
    }
    _vertexes = _classname.size();
```

```
    int mat[_vertexes][_vertexes];
    for (int i = 0; i < _vertexes; ++i) {
        for (int j = 0; j < _vertexes; ++j) {
            mat[i][j] = 0;
            if (_classname[j]._havePre) {
                //j的前驱是i，也就是i的后继是j matrix[i][j]置1
                for (auto it = _classname[j]._pre.begin(); it !=
_classname[j]._pre.end(); ++it) {
                    if (*it == _classname[i]._number) {
                        mat[i][j] = 1;
                    }
                }
            }
        }
    }

    for (int i = 0; i < _vertexes; ++i) {
        for (int j = 0; j < _vertexes; ++j) {
            _matrix[i][j] = mat[i][j];
        }
    }
}
```

2. Adjacency matrix construction diagram

input file:

in.txt

课程编号	课程名称	学时数	指定开课学期	先修课程
c01	程序设计基础	5	0	
c02	离散数学	6	0	c01
c03	数据结构算法	4	0	c01 c02
c04	汇编语言	5	0	c01
c05	算法设计	4	0	c03 c04
c06	计算机组成原理	6	0	
c07	微机原理	4	0	c03
c08	单片机应用	3	0	c03
c09	编译原理	5	0	c03
c10	操作系统原理	4	0	c03
c11	数据库原理	5	0	c03
c12	高等数学	6	0	
c13	线性代数	6	0	
c14	数值分析	6	0	c12
c15	普通物理	4	0	c12
c16	计算机文化	3	0	
c17	计算机系统结构	6	0	c06
c18	计算机网络	5	0	c03
c19	数据通信	6	0	
c20	面向对象程序设计	3	0	c01 c03
c21	Java	3	0	c01 c03
c22	C#.net	5	0	c01 c03
c23	PowerBuilder	5	0	c01 c03
c24	VC++	3	0	c01 c03
c25	ASP程序设计	5	0	c01 c03
c26	JSP程序设计	5	0	c01 c03
c27	VB.net	5	0	c01 c03
c28	Delphi	5	0	c01 c03
c29	C++Builder	5	0	c01 c03
c30	英语	5	1	
c31	英语	5	2	
c32	英语	5	3	
c33	英语	5	4	
c34	英语	5	5	
c35	英语	5	6	
c36	英语	5	7	
c37	英语	5	8	
c38	大学语文	3	1	

out put:

```
009
/Users/xuedixuedi/lxdThings/Code/github/Data-Structure-design/009/cmake-build-debug/009
0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1 0 1 1 1 1 1 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

3.3 Implement of finding Topological Sorting Sequences

1. Finding Topological Sorting Sequences core function

```
std::vector<Course> Graph::topologicalSort() {
    std::vector<Course> ans;
    for (int i = 0; i < _classname.size(); ++i) {
        if (findInDegree(_classname[i])) {
            //把入度为0的节点放入
            ans.push_back(_classname[i]);
            //把这个点的后继节点入度-1
            for (int j = 0; j < _classname.size(); ++j) {
                if (_matrix[i][j] == 1) {
                    _classname[j]._degree--;
                }
            }
        }
    }
    _classlist = ans;
```

```
    return ans;
}
```

2. Diagram

input file:

in.txt

课程编号	课程名称	学时数	指定开课学期	先修课程
c01	程序设计基础	5	0	
c02	离散数学	6	0	c01
c03	数据结构算法	4	0	c01 c02
c04	汇编语言	5	0	c01
c05	算法设计	4	0	c03 c04
c06	计算机组成原理	6	0	
c07	微机原理	4	0	c03
c08	单片机应用	3	0	c03
c09	编译原理	5	0	c03
c10	操作系统原理	4	0	c03
c11	数据库原理	5	0	c03
c12	高等数学	6	0	
c13	线性代数	6	0	
c14	数值分析	6	0	c12
c15	普通物理	4	0	c12
c16	计算机文化	3	0	
c17	计算机系统结构	6	0	c06
c18	计算机网络	5	0	c03
c19	数据通信	6	0	
c20	面向对象程序设计	3	0	c01 c03
c21	Java	3	0	c01 c03
c22	C#.net	5	0	c01 c03
c23	PowerBuilder	5	0	c01 c03
c24	VC++	3	0	c01 c03
c25	ASP程序设计	5	0	c01 c03
c26	JSP程序设计	5	0	c01 c03
c27	VB.net	5	0	c01 c03
c28	Delphi	5	0	c01 c03
c29	C++Builder	5	0	c01 c03
c30	英语	5	1	
c31	英语	5	2	
c32	英语	5	3	
c33	英语	5	4	
c34	英语	5	5	
c35	英语	5	6	
c36	英语	5	7	
c37	英语	5	8	
c38	大学语文	3	1	

out put:

```
/Users/xuedixuedi/lxdThings/Code/github/Data-Structure-design/009/cmake-build-debug/009
数据通信 计算机文化 线性代数 高等数学 普通物理 数值分析 计算机组成原理 计算机系统结构 程序设计基础
  汇编语言 离散数学 数据结构算法 C++Builder Delphi VB.net JSP程序设计 ASP程序设计 VC++
 PowerBuilder C#.net Java 面向对象程序设计 计算机网络 数据库原理 操作系统原理 编译原理 单片机
 应用 微机原理 算法设计
```

3.4 Schedules Excluded Each Semester

1. Output file core code:

```
void arrangeClass(int sem, Graph *gr) {
    int ttime = 0;//这些课程的总时间
    vector<Course> list;
    for (int i = 0; i < gr->_name.size(); ++i) {
        if (gr->_name[i]._semester == sem) {
            list.push_back(gr->_name[i]);
            ttime += gr->_name[i]._time;
        }
```

```
    }

    if (!gr->_classlist.empty()) {
        for (auto it = gr->_classlist.begin(); it != gr->_classlist.end(); ++it) {
            if (it->_semester == 0) {
                ttime += it->_time;
                list.push_back(*it);
                it->_semester = sem;
            }
            if (ttime > 20) {
                break;
            }
        }
    }

    outPut(sem, list);

}
```

```
//输出文件:
void outPut(int sem, vector<Course> ls) {
    string xx = "../out0.txt";
    xx[6] = static_cast<char> (sem);
    auto str = xx.c_str();
    ofstream out;
    out.open(str);
    out << "The " << sem << " semester's curriculum:" << endl;

    //我想先把ls按照课时数排一排
    sort(ls.begin(), ls.end(), cmp);
    for (int i = 0; i < ls.size(); ++i) {
//        cout << ls[i]._time << ' ';
    }

    int classtime[ls.size()];//对应课程的课时
    vector<Course> schedual;
    for (int i = 0; i < ls.size(); ++i) {
        classtime[i] = ls[i]._time;
    }

    for (int k = 0; k < 3; ++k) {
        for (int i = 0; i < ls.size(); ++i) {
            if (classtime[i]) {
                if (classtime[i] % 2) {
                    //奇数情况
                    schedual.push_back(ls[i]);
                    schedual.push_back(ls[i]);
                    schedual.push_back(ls[i]);
                    classtime[i] -= 3;
                } else {
                    //偶数情况
```

```
                    schedual.push_back(ls[i]);
                    schedual.push_back(ls[i]);
                    classtime[i] -= 2;
                }
            }
        }
    }

    int hd = 4;
    int num = 0;
    string temp1;

    for (int i = 0; i < schedual.size(); ++i) {
        num++;
        out << schedual[i]._name << '|';
        if (schedual[i]._number != schedual[i + 1]._number && schedual[i]._number == schedual[i - 2]._number) {
            num++;
            out << "     |";
        }
        if (num == 4) {
            num = 0;
            out << endl;
        }
    }

    out.close();

}
```

2. Output timetable

Semester 1:

Mon	Tues	Wed	Thri	Fri
数据通信	程序设计基础	程序设计基础	数据通信	
数据通信	计算机文化	程序设计基础	数据通信	
数据结构	计算机文化	程序设计基础	数据结构	英语
线性代数			线性代数	英语
英语	大学语文			程序设计基础
英语	大学语文			程序设计基础
英语	大学语文			

Semester 2:

Mon	Tues	Wed	Thri	Fri
计算机组成原理	英语	计算机组成原理	普通物理	计算机组成原理
计算机组成原理	英语	高等数学	普通物理	计算机组成原理
数值分析	英语	数值分析	英语	数值分析
数值分析		数值分析	英语	数值分析
普通物理	离散数学		离散数学	
普通物理	离散数学		离散数学	
	离散数学		离散数学	

Semester 3:

Mon	Tues	Wed	Thri	Fri
计算机组成原理	数据结构算法	英语	数据结构算法	操作系统原理
计算机组成原理	数据结构算法	英语	数据结构算法	操作系统原理
计算机系统结构		英语		英语
计算机系统结构				英语
		计算机组成原理		计算机系统结构
		计算机组成原理		计算机系统结构
		计算机系统结构		计算机组成原理
		计算机系统结构		计算机组成原理

Semester 4:

Mon	Tues	Wed	Thri	Fri
汇编语言			汇编语言	

汇编语言		汇编语言	
汇编语言		C++Builder	
		C++Builder	
C++Builder	英语		英语
C++Builder	英语		英语
C++Builder	英语		

Semester5:

Mon	**Tues**	**Wed**	**Thri**	**Fri**
Delphi	VB.net	计算机系统结构	Delphi	
Delphi	VB.net	计算机系统结构	Delphi	
Delphi	VB.net		英语	
			英语	
英语	JSP程序设计			VB.net
英语	JSP程序设计			VB.net
英语	JSP程序设计			JSP程序设计
				JSP程序设计

Semester6:

Mon	**Tues**	**Wed**	**Thri**	**Fri**
C#.net		PowerBuilder	C#.net	PowerBuilder
C#.net		PowerBuilder	C#.net	PowerBuilder
C#.net		PowerBuilder		VC++
				VC++
		VC++	英语	Java
		VC++	英语	Java

英语	VC++		英语	Java
英语				

Semester7:

Mon	**Tues**	**Wed**	**Thri**	**Fri**
计算机网络	数据库原理	操作系统原理	计算机网络	数据库原理
计算机网络	数据库原理	操作系统原理	计算机网络	数据库原理
计算机网络	数据库原理		英语	操作系统原理
			英语	操作系统原理
英语				面向对象程序设计
英语				面向对象程序设计
英语				面向对象程序设计

Semester8:

Mon	**Tues**	**Wed**	**Thri**	**Fri**
编译原理	算法设计		编译原理	微机原理
编译原理	算法设计		编译原理	微机原理
编译原理	微机原理		英语	算法设计
	微机原理		英语	算法设计
英语				单片机应用
英语				单片机应用
英语				单片机应用

4. Test

4.1 Error test

Fail to open the file

input:

A txt file with wrong name

Expected outcome:

Error opening file

Experimental result: