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Student's Itineraries Through Bachelor Degree Programs in NBU

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Abstract

The paper presents a mathematical model for a choice of the student's own path of teaching in a Bachelor Program in New Bulgarian University. Every path has to be individual and satisfying the NBU rules. The curriculum is described as a directed acyclic graph with nodes – the courses' and edges – the connections (prerequisites) between courses. The choice of the path by the students is a task for finding itinerary in the graph. The model has a program realization in C++ and input data are for the Bachelor Program *Networking Technologies*. The results and their interpretation are shown too.

Background

To choose the courses for a term, the student has to read in advance the course passport, where the course syllabus is presented as well as a list of courses as prerequisites.

What are the reasons a student does or does not choose a course proposed for the term?

The reasons to choose

- The student thinks that he/she has an idea about the course but the course will extend his/her knowledge in this area.
- The student thinks that the knowledge and skills obtained in the course will be useful for him/her.

The reasons not to choose

- The student supposes that he/she already has knowledge and skill which the course offers.
- The student thinks that the course is not useful for him/her.

The reasons to choose

- The student supposes that the subject is easy enough and the corresponding credits could be took without efforts.
- The student considers that the lecturer is very competent in the area and it is worth to learn something from this lecturer.
- Program director recommends persistently this course.

The reasons not to choose

- The student supposes that the subject of the course is too difficult and he/she could have a problem to take the exam.
- The student considers that the lecturer is not competent in the area and it is pointless to spend the time participating the course.
- Program director does not recommend this course.

Some possible criteria which are not very enough working in practice are:

- I will enroll this course because it is included in prerequisites of a course which I like to pass next term.

- I can not enroll this course because I have not passed a course included in prerequisites.
- I do not enroll the course because I manage myself in this matter.

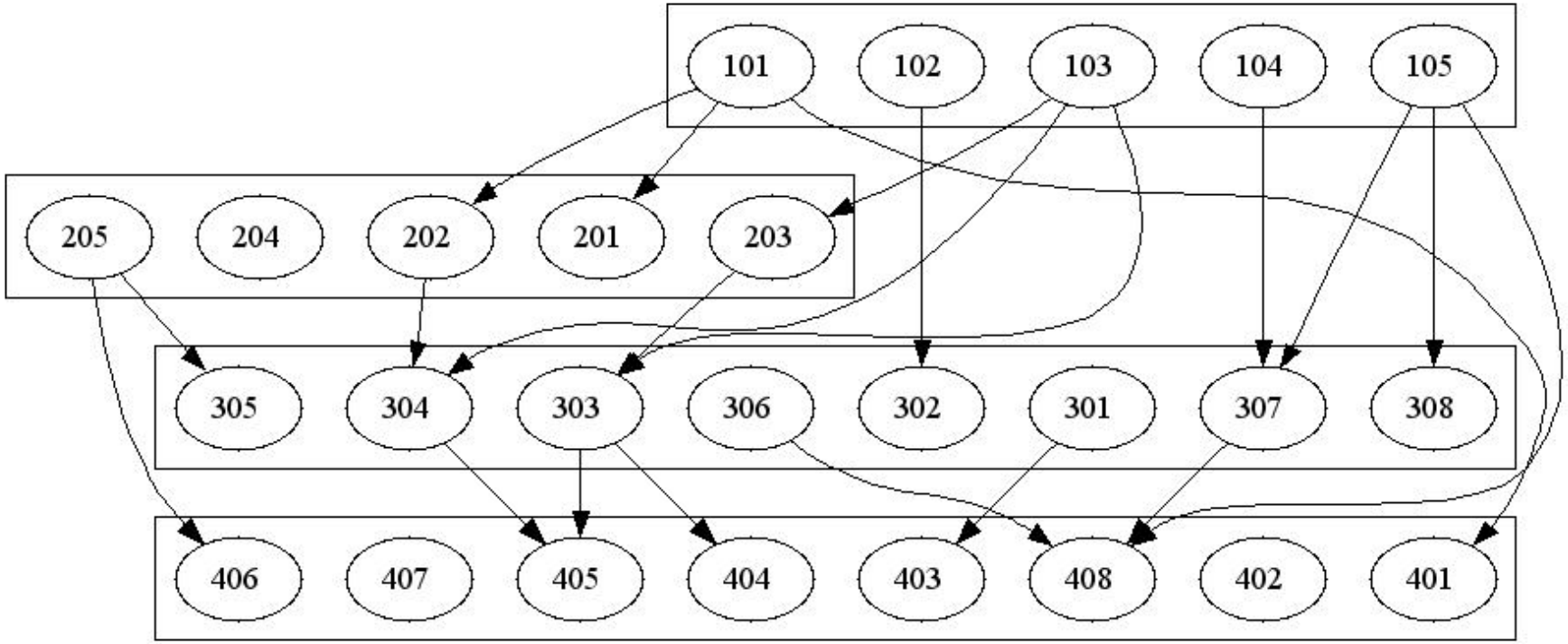
Mathematical Model

- Every student has to choose for every term m_i courses from M_i offered by a given program ($m_i < M_i$, $i = 1, 2, ..., n$).
- The current rules for bachelor programs in NBU are:
  - for $i = 1, 2$ (first year), the choice is 3 from 5 courses ($m_i = 3$, $M_i = 5$);
  - for every next term, $i = 3, 4, 5, 6, 7, 8$, the choice is 6 from 8 ($m_i = 6$, $M_i = 8$).

The student's itinerary is a list of courses, which a student could enroll satisfying all background requirements.

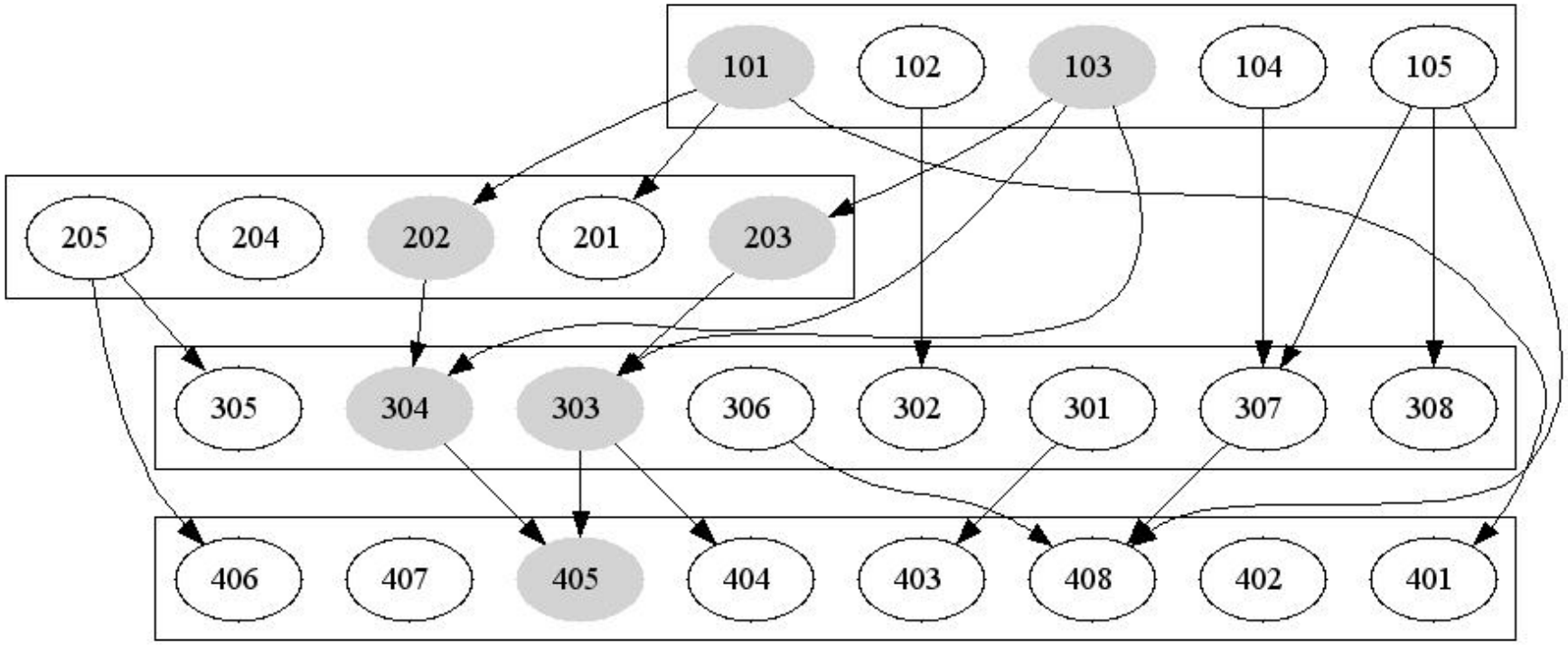
- The curriculum is modeled as a directed acyclic graph (DAG) with nodes the courses' signatures and edges – the connections (prerequisites) between courses.
- Every node has a level – term number, when this course is offered.
- The start node of every edge has less level than the end node.
- The curriculum is not a tree because a node may have more than one predicator.
- The graph may not be connected.

Examples and Definitions



An example of a graph of curriculum for 4 terms.

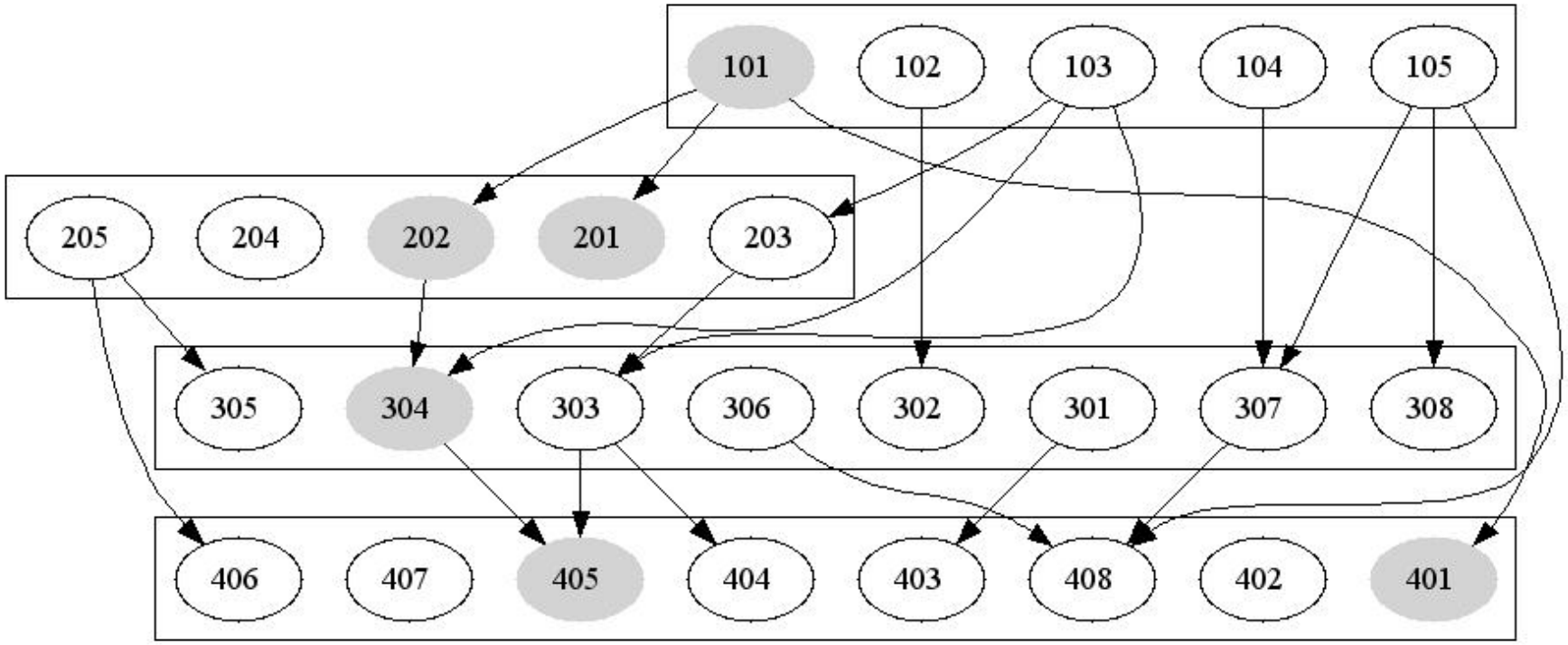
Examples and Definitions



Itinerary subgraph is called a subgraph, which contains nodes and all their predicators.

The logic is: If a student wants to enroll a course, he/she has to be already enrolled all courses from the *minimal itinerary subgraph*, which contains this course (405).

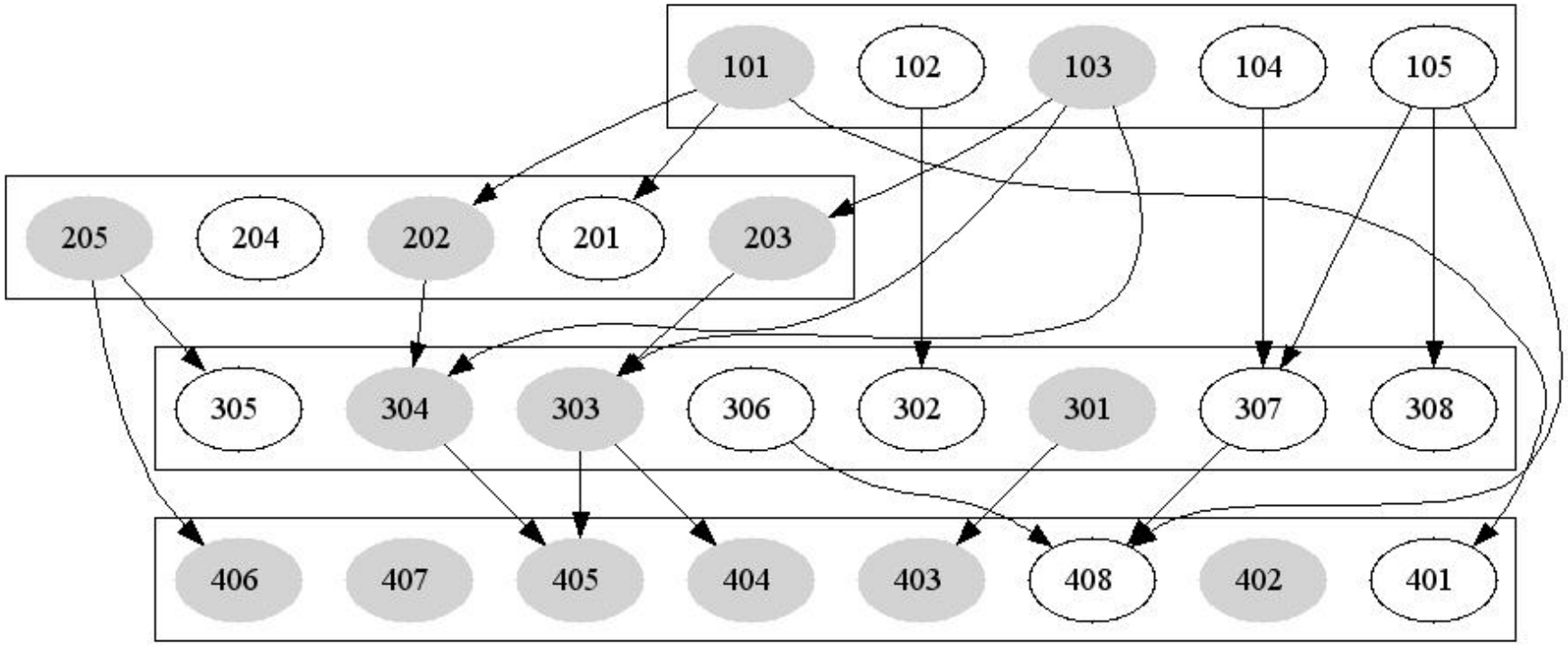
Examples and Definitions



Nonitinerary subgraph is called a subgraph, which contains nodes and all their successors.

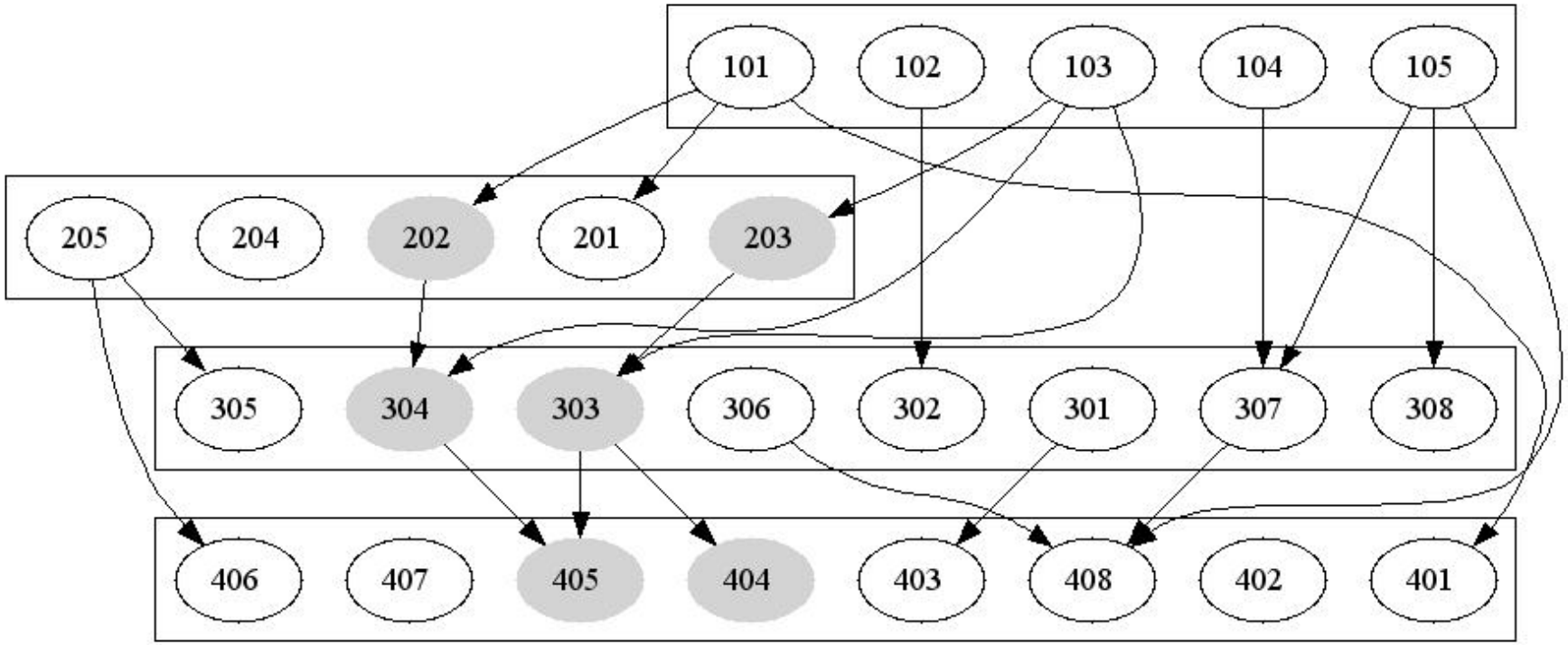
The logic is: If a student do not enroll a course, then he/she cannot enroll all courses from the *minimal nonitinerary subgraph*, which contains this course (101).

Examples and Definitions



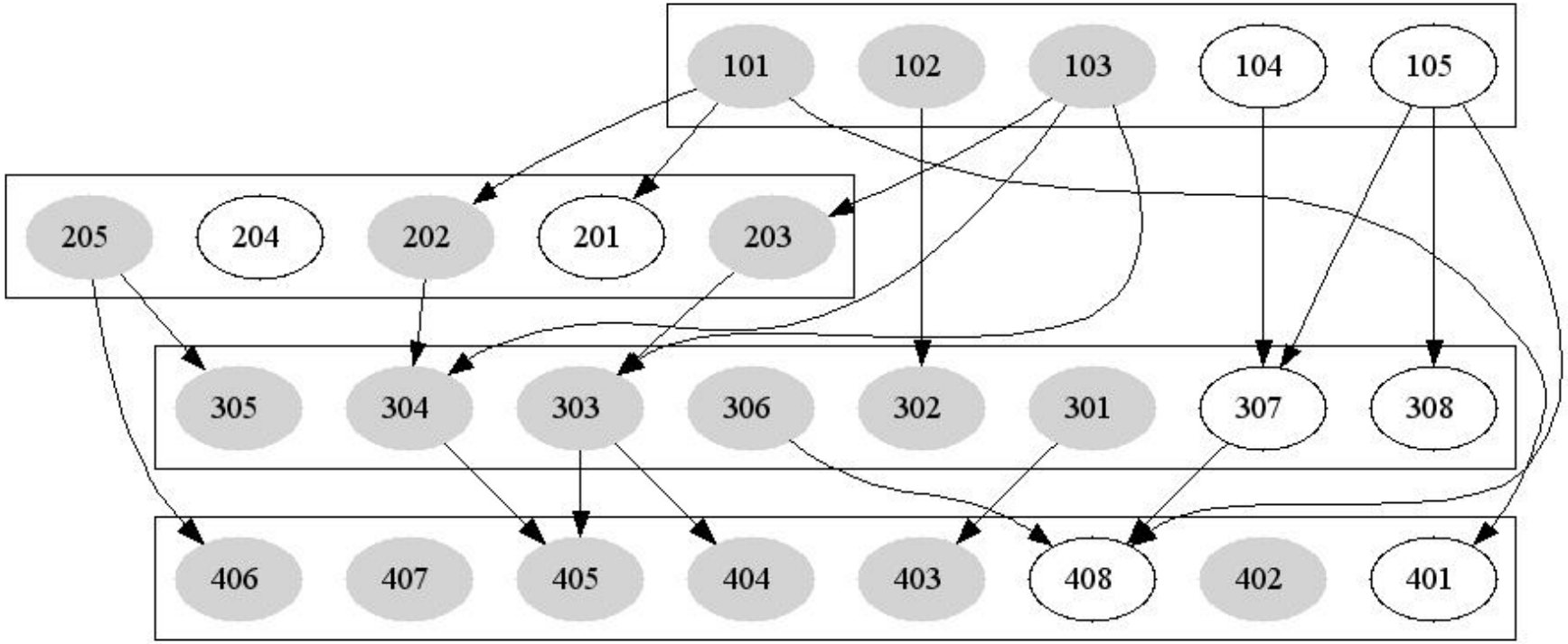
- *i-complete itinerary subgraph* is called an itinerary subgraph which contains exact m_i courses of i-th term ($i = 2, 4$).
- We denote by i-CMIS an *i-complete minimal itinerary subgraph* ($i = 4$).

Examples and Definitions



- *i-complete nonitinerary subgraph* is called a nonitinerary subgraph which contains exact $M_i - m_i$ courses of i-th term ($i = 2, 3, 4$).
- We denote by i-CMNS an *i-complete minimal nonitinerary subgraph* ($i = 2$).

Examples and Definitions



Students itinerary through a curriculum (or simply *itinerary*) is called an itinerary subgraph, which contains exact m_i nodes of level i, i.e. an i-complete itinerary subgraph for every $i = 1, 2, \ldots, n$.

Tasks

Task 1. For a concrete curriculum find:

- at least one itinerary through a curriculum, if exists;
- the number of all itineraries;
- all itineraries.

Task 2. For a concrete curriculum and a set of chosen courses find:

- at least one itinerary which contains the set, if exists;
- all itineraries which contain the set.

Task 3. For a concrete curriculum and a set of chosen courses find:

- minimal itinerary subgraph which contains the set;
- minimal nonitinerary subgraph which contains the set.

Notations ...

- Let a_{ij} be a code of j-th course of term i, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, M_i$, i.e. the graph nodes are a_{ij}, and i is the node level. Let $x_{ij} \in \{0, 1\}$ be a variable, which shows whether the course a_{ij} is or is not chosen.

- i-th term a student chooses a subset of m_i elements from the set $\{a_{i1}, a_{i2}, \ldots a_{iM_i}\}$, i.e. $\sum_{j=1}^{M_i} x_{ij} = m_i$ for every i.

- Edges are ordered pairs $(a_{i_1 j_1}, a_{i_2 j_2})$, where $i_1, i_2 \in \{1, 2, \ldots, n\}$, $i_1 < i_2$, $j_1 \in \{1, 2, \ldots, M_{i_1}\}$, $j_2 \in \{1, 2, \ldots, M_{i_2}\}$.

- To enroll the course $a_{i_2 j_2}$, the student must have the background knowledge from the course $a_{i_1 j_1}$, i.e. $x_{i_2 j_2} \leq x_{i_1 j_1}$.

... and a Model

- Students itinerary is every point from a set, defined by the following equations and inequalities:
  - $\sum_{j=1}^{M_i} x_{ij} = m_i$ for every $i = 1, 2, \ldots, n$,
  - $x_{i_2 j_2} \leq x_{i_1 j_1}$ for an edge from $a_{i_1 j_1}$ to $a_{i_2 j_2}$, $1 \leq i_1, i_2 \leq n,\ 1 \leq j_1 \leq M_{i_1},\ 1 \leq j_2 \leq M_{i_2}$.
  - $0 \leq x_{ij} \leq 1$ – integer numbers.
- Adding an arbitrary (linear) objective function, we obtain a classic integer programming problem.

Curriculum of the Bachelor Program Networking Technologies

- The program Networking Technologies is a new bachelor program of Computer Science department of NBU.
- Following the rules of the university, every course must take one term and 30 hours. For that reason some courses are coupled, most often lectures and labs at the same topic. The students are recommended to enroll both courses of the pair.
- Every course has an identification number (signature) and pairs are connected by &.
- The curriculum is divided in two modules: *System Administration* and *Internet Programming*, which are disposed in 3-th and 4-th years of education.
- Now the students can choose any course from both modules.

Courses in Networking Technologies

Y	T		C	o	u	r	s	e	s			
1	1	3 5	101&121	102	103&123							
1	2	3 5	151&171	153&173	154							
2	3	6 8	201&221	202&222	206&226	253	294					
2	4	6 8	205&225	254&284	257&277	258&278						
3	5	6 8(14)	274	302	307&317	324&334	341	359	301&311	303	305	321 343
3	6	6 8(11)	352&362	356	357	358&368	371	391	351	353&373		
4	7	6 8(12)	401&411	404&414	409&419	434	435	421	408&418	422		
4	8	6 8(13)	452	454	457&467	474&484	470	464	451&461	458&468	478	

The courses in the module *System Administration* are in **black** and red, but those in the module *Internet Programming* are in **black** and blue.

There are 76 courses in the curriculum – 25 double and 26 single, i.e. the graph represented the program has 51 nodes. Edges are 76.

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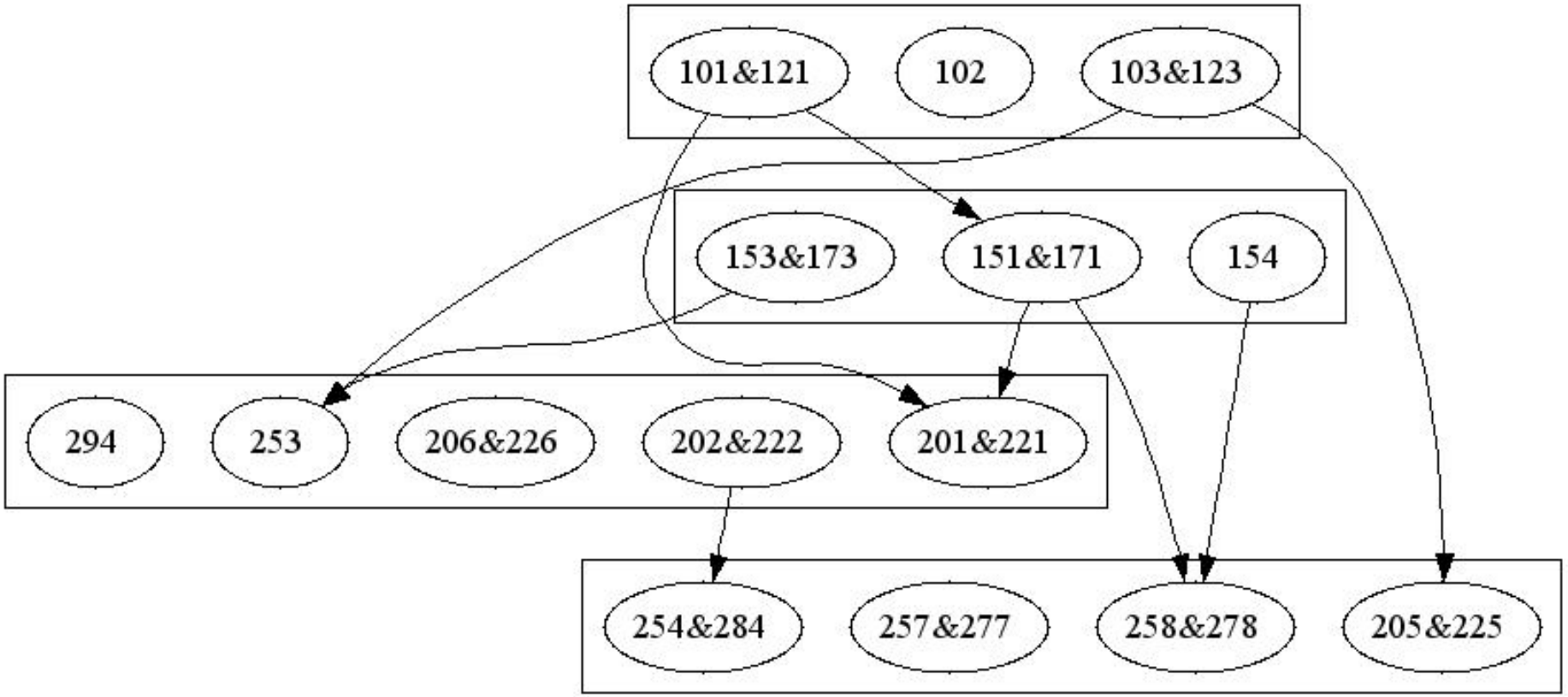
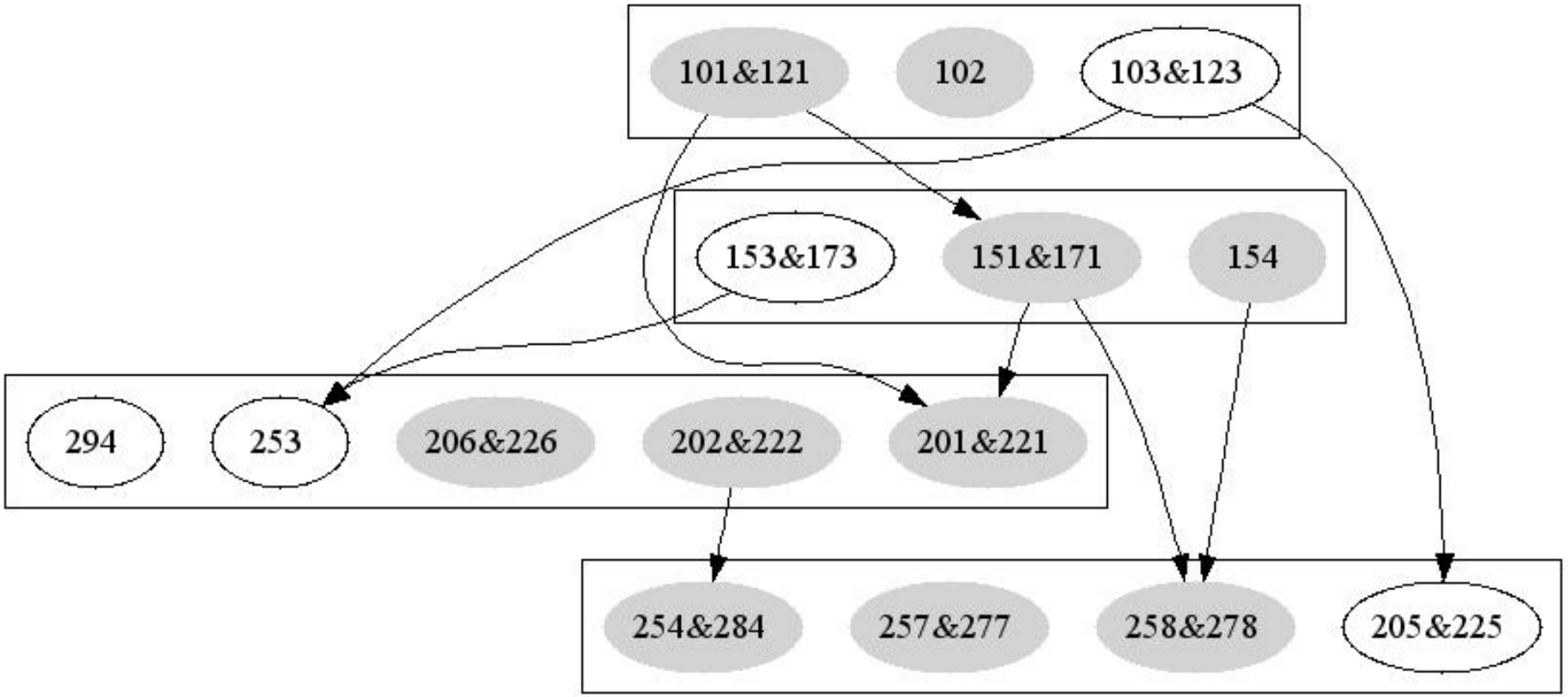
First and second years in Networking Technologies



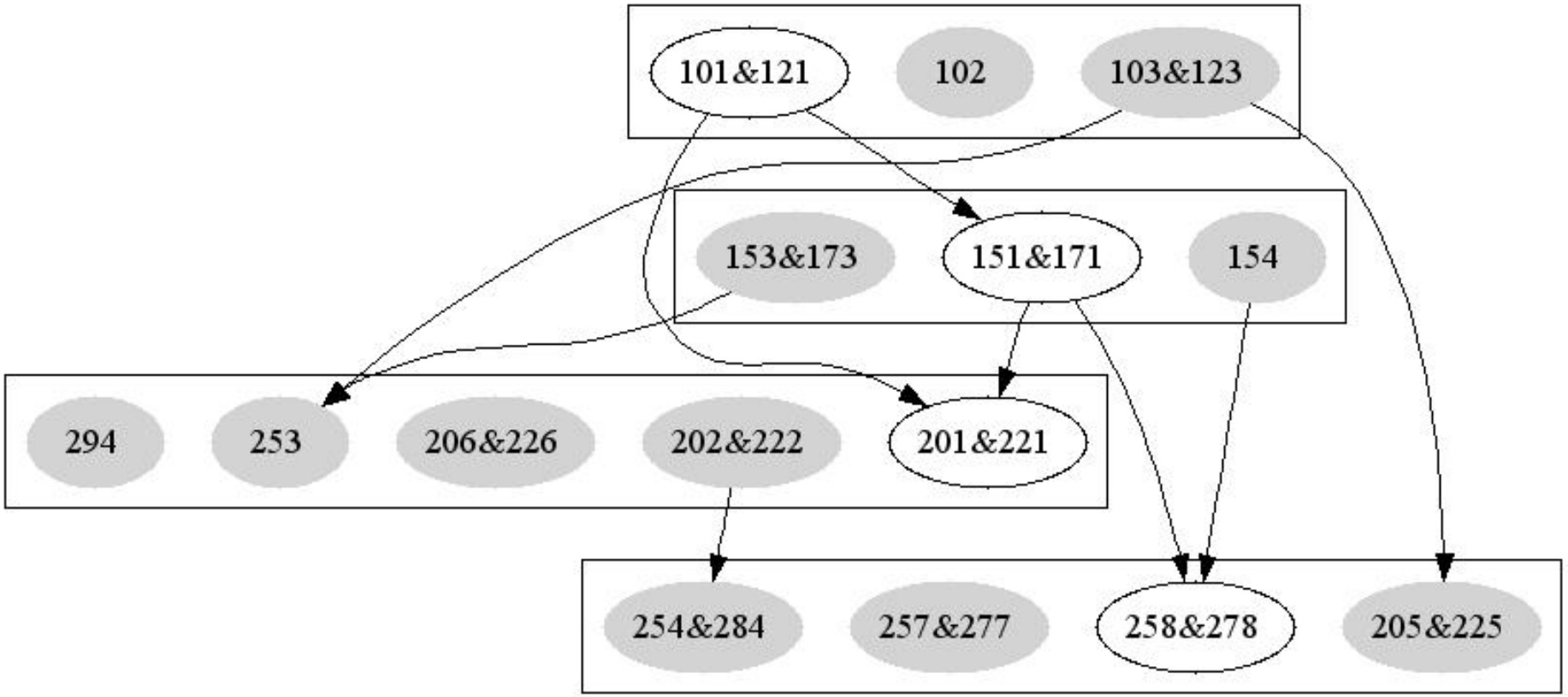
- There are two i-CMIS for $i = 1, 2$, when the choice is 3 courses.
- There are several i-CMIS for $i = 3, 4$, when the choice is 6 courses.

First and second years in Networking Technologies



- There exist itineraries in those 4 semesters (without taking into account the connections with next semesters)

First and second years in Networking Technologies



- There exist itineraries in those 4 semesters (without taking into account the connections with next semesters)

Results for curriculum Networking Technologies

(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	1	3	5	1	1	1
1	2	3	5	2	2	2
2	3	6	8	2	1	1
2	4	6	8	2	1	1
3	5	6	14	120	22	22
3	6	6	11	20	344	344
4	7	6	12	13	0	876
4	8	6	13	84	0	15 312

(a) Year
(b) Term
(c) Number of courses to be chosen
(d) Number of courses offered
(e) Number of i-CMIS
(f), (g) Number of itineraries to the corresponding term

There is no itinerary through curriculum *Network Technologies*! In the seventh semester it is impossible to choose 6 courses, as we can see in the column (f) of the table.

`itiner.txt`

But if we remove only one edge (from 294 to 401&411), then a lot of itineraries arise – its number is given in the column (g).

Requirements to the lecturers and relaxed task

- Every lecturer has to define clearly the courses which are necessary for successful learning the material in its course.
- Every lecturer defines two types of preliminary courses:
  - necessary;
  - recommended.
- In this case the graph consists of two types of edges – necessary and recommended. The problems can be solved for necessary edges only.
- Optimistic case
  - In the choice of several solutions it can be added an optimization criterion using recommended edges.

- Pessimistic case
  - If there is no solution, the content of some courses should be changed. The decision for these courses could be defined as solutions of optimization problems.
  - For example removing minimal number of edges from the graph in order to obtain at least one solution.

The Benefit

The solutions of our model can answer the following questions which are important for curriculum designers:

- How many itineraries exist in a given programme?
- Is a course included in any itinerary?
- How many itineraries includes a given course?
- What is the real choice of a student?
- In case of offering several necessary courses, what is the restriction in the students choice?

The Benefit

For the students the benefits of this model are:

- Every semester a student can choose an itinerary or a set of itineraries, which guarantee the possibility of successful completion the program.
- In addition, the student can get information about nonitinerary subgraph, which contains the courses which the student does not enroll for a given term. The subgraph consists of all courses which the student cannot enroll all next terms.

Thank you for the attention.