notes

- we are several authors from several institutes
- some of us are MSc students, some PhDs (in language education), some faculties in engineering
- we have been all involved in collecting and processing data in Luleå and Uppsala for different engineering-oriented programs

Courses-Concepts-Graphs as a Tool to Measure the Importance of Concepts in University Programmes

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notes

- in brief, we do as written here
- and now we will see why, what, and how we do this in a more precise way

In a nutshell

use graph-theoretic tools

to check the logical consistency

of university programs

notes

- the first thing is explaining our why's
- as teachers we often relied on the assumption that students have already learned the required prerequisite knowledge

Why?

- how often do we assume that students know the prerequisites?

notes

- and in our small experience very often this is not the case
- talking with colleagues, this seems a widespread phenomenon
- just as anecdotal experience, in some years more than 20% of 4th year students do not know basic rules about complex numbers

Why?

- how often do we assume that students know the prerequisites?
- how often does this assumption hold?

notes

- but where is the fault? Are the students that forgot? Are the teachers that did not teach the things? Or did not teach them at the right level? Might it be that we, as teachers, typically make assumptions on what is taught before us, but actually we are doing wrong assumptions because there have been some changes and we don't know? Is it a combination of all these factors?
- the problem is that at least us, the authors of this paper, don't have some tools that help us answer these questions

Why does this happen?

- did students forget things?
- did teachers omit teaching?
- is our perception of the program contents obsolete?

notes

- what can we do to solve this?
- what we decided to try is to start from developing strategies to analyse if there is some flaw in the teaching content and that help both us teachers and the students be aware of what is the planned teaching content
- and what we saw is that there is no widely used tool to create and maintain maps of what is taught, when, and at which level, during the program, that has the characteristics that we will present in 2 minutes

How can we solve this?

notes

- what we believe is best is to have a tool that:
- is “cooperative” so that it makes people collaborate, in the sense that each teacher gives her or his inputs and it is not something that comes from above - this should promote inclusiveness and collegiality and other positive qualities
- is “adaptive” in the sense that each institution can modify it for their own purposes, and in this way make it so that it can capture the peculiarities of their own program
- is "distributed", in the sense of being able to combine local information from single courses (read: single teachers) into some global information on the whole program, so that there is no need for people that has a global knowledge about everything
- is "asynchronous", in the sense of working even if people add their information to the system at different times, so that there is no need to organize program-wide meetings (we know that we are all very busy)

Sought qualities

- cooperative
- adaptive
- distributed
- asynchronous

notes

- the final aim is to have something that simplifies our life; since we believe in automatic control, we would like something useful to automate the analysis of the properties of the program and gives computer-assisted indications on how to take corrective actions if we detect something suboptimal

Sought qualities

- cooperative
- adaptive
- distributed
- asynchronous

- enabling quantitative analyses of the logical coherence of our programs

notes

- we now show the first version of the method that we devised; later we discuss the latest developments, that introduced some interesting things. In any case what we show here is instrumental to see the big picture
- so the first step we propose is to summarize a program in terms of its KCs, that means the basic facts, concepts and procedures that define the core of what our students should learn and know
- an example from an actual field case is the following – of course here we are plotting only a subset of the KCs
- as for compiling the common list of KCs at that time we did some chats with teachers and compiled a list that we then refined little by little; now we are testing an approach where we initially do this list using natural language processing tools, so to have a first version faster
- note moreover that we do not have time here to discuss the problem of deciding the model structure, in the sense of the granularity of these descriptions - we are having some ongoing work there. So pretend in this talk that we somehow know how many KCs we should use

Envisioned method

(when we submitted the first version)

1. compile a common list of *"Knowledge Components"* (KCs)

complex numbers
vectors
lin. systems of eq.
Ohm's law
⋮

notes

- then we add information on which courses are present in the program, so that we have a matrix

Envisioned method

(when we submitted the first version)

1. compile a common list of *"Knowledge Components"* (KCs)
2. create a *"KCs vs. courses"* matrix

	R7003E	R7008E	E7015F	...
complex numbers				
vectors				
lin. systems of eq.				
Ohm's law				
⋮				

notes

- then add some labels that associate each concept to each course
- for who has heard about the CDIO framework, this is similar to the black-box approach to the determination of program contents, only made in an asynchronous way
- importantly, we can interpret this matrix as a bipartite graph

Envisioned method

(when we submitted the first version)

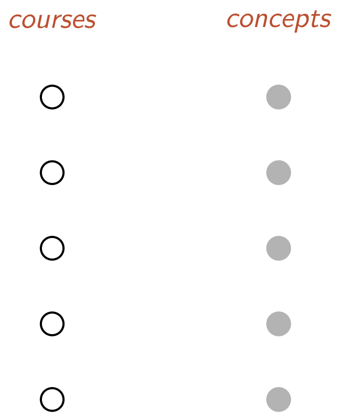
1. compile a common list of *"Knowledge Components"* (KCs)
2. create a *"KCs vs. courses"* matrix
3. let each teacher fill her/his row with
   - “0 (i.e., not important)”
   - “1 (i.e., somewhat important)”
   - “2 (i.e., important)”

	R7003E	R7008E	E7015F	...
complex numbers		2	1	
vectors	1			
lin. systems of eq.	1		2	
Ohm's law		2	1	
⋮				

notes

- the intuition is that some quantitative properties of the graph can give insights on the logical properties of the program

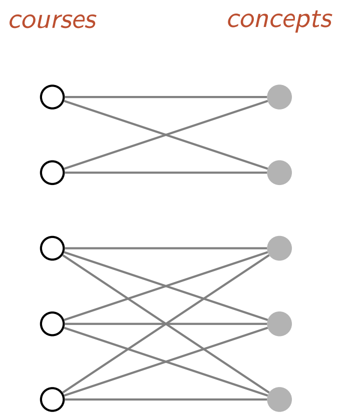
Mathematical interpretation as a weighted undirected bipartite graph



notes

- a first example is when there are some disconnected components, that mean some "non-connected KCs"
- this in a sense indicates the existence of parts of the program that work as “independent components”
- it may absolutely be something desirable; however it is good if students, teachers and specially boards are quantitatively aware of this

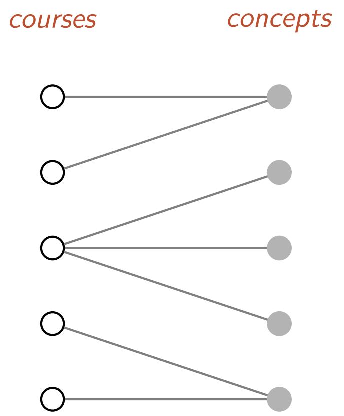
Mathematical interpretation as a weighted undirected bipartite graph



notes

- another example is when there are some concepts that are taught and/or used only by one course
- also this may be desirable; however intuitively a situation like this may be associated to a sort of lack of resiliency: if for certain reasons that course is taught in a suboptimal way or a student was having some issues that made him/her underperform in that course, then there is no "backup"

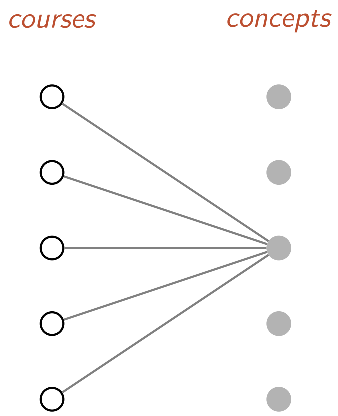
Mathematical interpretation as a weighted undirected bipartite graph



notes

- and an last simple example is that maybe sometimes we teach the same stuff over and over again, maybe even too often, and we are inefficient in how we use our time

Mathematical interpretation as a weighted undirected bipartite graph



notes

- we implemented this in two field cases
- one of them is partially shown here

Mathematical interpretation as a weighted undirected bipartite graph

A field example from the electrical engineering program in Uppsala, year 2017

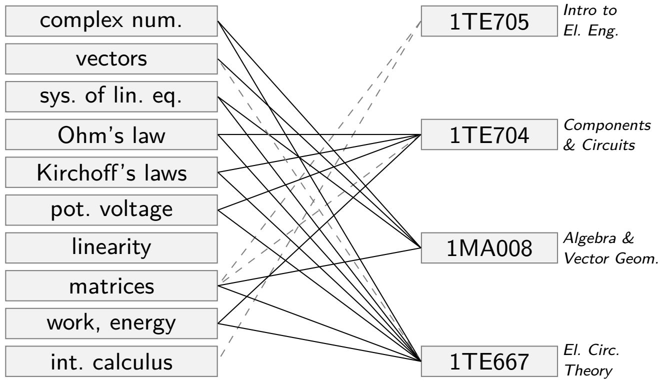
	1TE705 Intro to El. Eng.	1TE704 Components & Circuits	1MA008 Algebra & Vector Geom.	1TE667 El. Circ. Theory
complex num.			2	2
vectors			2	1
sys. of lin. eq.			2	2
Ohm's law		2		2
Kirchoff's laws		2		2
pot. voltage		2		2
linearity				
matrices	1	1	2	2
work, energy		2		2
int. calculus	1			

notes

- that part of the matrix that we shown before can be seen as a graph as this one
- without entering into details, we can guarantee you that just showing this information to the various teachers of the program raised a lot of discussions among the various teachers in the program, and it was clear that the teachers were thinking to be more aware on the program structure than what they actually were

Mathematical interpretation as a weighted undirected bipartite graph

A field example from the electrical engineering program in Uppsala, year 2017



notes

- we saw that this can work thus as a starting point for the teachers and students to align expectations
- moreover we have the intuition that having something that visualizes the study flow helps students get better intuitions of why it is important to study the various things
- plus teachers and board can simulate changes in the courses / program and detect problems from optimize things
- unfortunately the strategy does not very well tolerate "packet losses", "noise", and "bias"
- moreover this approach does not give detailed information about the actual flow of knowledge components, nor captures at which "learning depth" things are explained
- the question is thus: how can we improve it?

What does this enable?

- align expectations
- simulate effects of contents' changes

notes

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What does this enable?

- align expectations
- simulate effects of contents' changes

Drawbacks:

- not robust w.r.t. packet losses, noise, & bias
- based on non-sufficient statistics

notes

- first direction is to include taxonomy levels, that means add a way of indicating if students should know things at different levels and complexity of knowledge
- well developed topic in the pedagogics community, they can describe different types of knowledge levels with respect to different criteria
- there exist several types of taxonomies, some of them are very suitable for describing engineering-oriented knowledge
- distinguishing prerequisites with developed things enables more to move towards directed graphs, and thus add the possibility of interpreting the learning process as a flow
- this means that we can use "flow-oriented" graph analyses concepts as proxies for programs or courses logical coherences indicators

Current directions - main ingredients

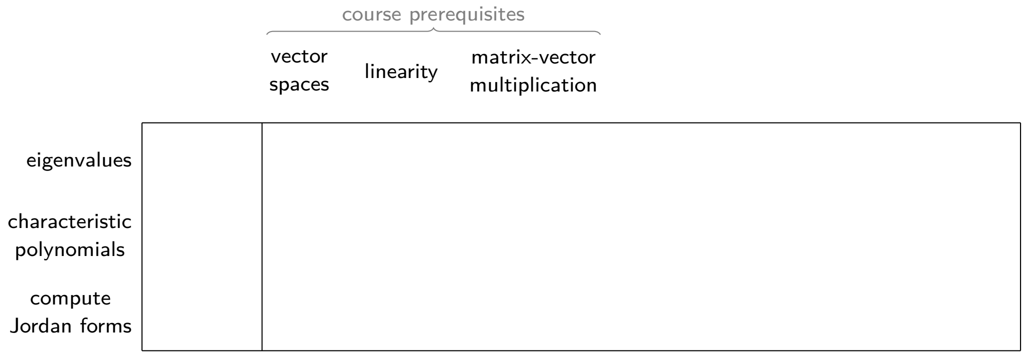
- include taxonomy levels
- consider directed graphs, distinguishing between prerequisites and developed knowledge components

notes

The envisioned workflow is as follows: assume that I am the teacher of the imaginary *course X*. As a starting point, as a teacher I am aware that there exist taxonomical knowledge levels, e.g., Bloom's, as we said before. Moreover, having designed or taught course X, I know that this course is characterized by a list of prerequisites, that are defined in terms of concepts and skills, and a list of ILO, that are also defined in terms of concepts and skills. Let's assume thus that I write down the list of the course prerequisites and the list of the ILO of this course in this way.

Current directions - example

Representing an imaginary *Course X* through directed-graphs representations



notes

Now assume that my experience as a teacher, or logical considerations, make me consider that to reach the first ILO students should ideally have a prerequisite learning level (again, using Bloom's taxonomy as an illustrative example) *2 - understand* for both prerequisite concepts *vector spaces* and *linearity*.

Current directions - example

Representing an imaginary *Course X* through directed-graphs representations

		course prerequisites		
		vector spaces	linearity	matrix-vector multiplication
eigenvalues		2	2	
characteristic polynomials				
compute Jordan forms				

notes

To be able to learn about *characteristic polynomials* students should ideally have a prerequisite learning level *2 - understand* for the skill *multiply matrices and vectors*, and have reached - while studying for *Course X* - a learning level *1 - remember* about the ILO *eigenvalues*. Note that since there is this potential situation for which to reach the second ILO students may need to learn the first ILO, the table that we are constructing needs to "repeat" the ILOs on the side of the prerequisites.

Current directions - example

Representing an imaginary *Course X* through directed-graphs representations

	course prerequisites			intended learning outcomes		
	vector spaces	linearity	matrix-vector multiplication	eigenvalues	characteristic polynomials	compute Jordan forms
eigenvalues	2	2				
characteristic polynomials			2	1		
compute Jordan forms						

notes

Then, to be able to learn the skill *compute Jordan forms* students should ideally have a prerequisite learning level *1 - remember* for the prerequisite *linearity* and level *2 - understand* about the ILO *eigenvalues* and *characteristic polynomials*.

Current directions - example

Representing an imaginary *Course X* through directed-graphs representations

		course prerequisites			intended learning outcomes		
		vector spaces	linearity	matrix-vector multiplication	eigenvalues	characteristic polynomials	compute Jordan forms
eigenvalues		2	2				
characteristic polynomials				2	1		
compute Jordan forms			1		2	2	

notes

To be also complete, I also add to this table information on which knowledge level students will ideally reach when successfully passing the course. As it will be clear later on, this information will be useful to analyze the structural properties of the programs that involve course X.

Current directions - example

Representing an imaginary *Course X* through directed-graphs representations

		course prerequisites			intended learning outcomes			intended final learning level
		vector spaces	linearity	matrix-vector multiplication	eigenvalues	characteristic polynomials	compute Jordan forms	
eigenvalues		2	2					3
characteristic polynomials				2	1			2
compute Jordan forms			1		2	2		3

notes

Finally, I may add additional information such as "amount of teaching time" dedicated to each ILO – or, in general, every information that we may discover be valuable for assessing the structural properties of the course and of the related program as a whole.

Current directions - example

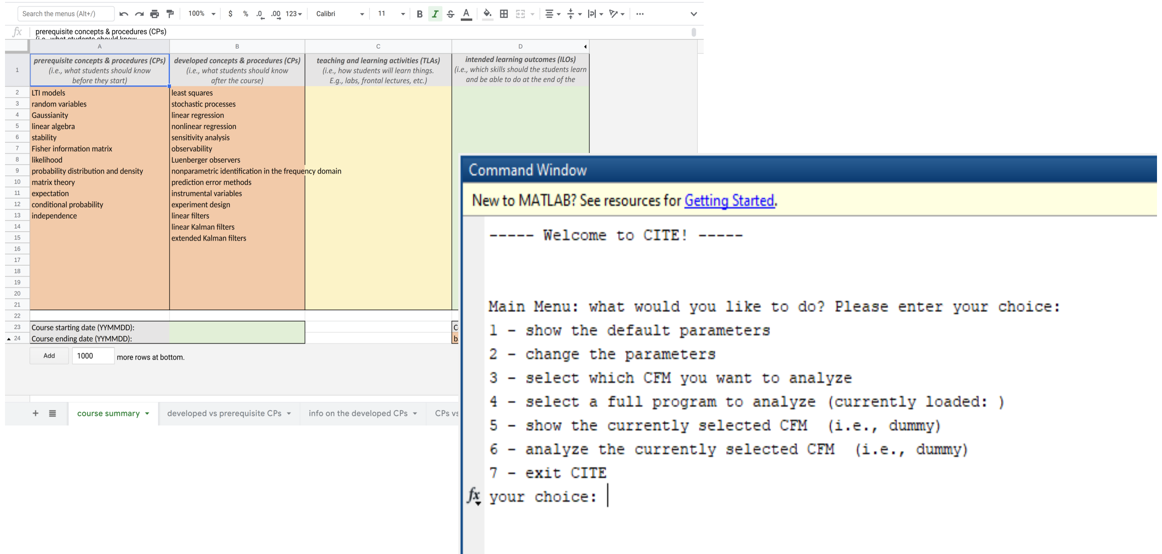
Representing an imaginary *Course X* through directed-graphs representations

		course prerequisites			intended learning outcomes			
	teaching time	vector spaces	linearity	matrix-vector multiplication	eigenvalues	characteristic polynomials	compute Jordan forms	intended final learning level
eigenvalues	45%	2	2					3
characteristic polynomials	20%			2	1			2
compute Jordan forms	35%		1		2	2		3

notes

- for now, this is done using a combination of google spreadsheet / excel and Matlab, but it can be generalized to anything one wants
- our code and templates are public, also the new versions that we will present later, if you want to use them or provide feedback

How does the tool look like?



notes

- in brief, we did, are doing, and plan to continue doing as written here
- for now everything is simple, but we are keen to become more sophisticated from both mathematical and pedagogical perspectives

In a nutshell

use graph-theoretic tools

to check the logical consistency

of university programs

notes

- when applying our framework to field cases we discovered things

Discussion

(more than "conclusions")

- every field case revealed unforeseen inconsistencies

notes

- moreover we got very positive responses from teachers and requests of doing ad-hoc workshops with teachers from other programs than ours, and help implement the data collection and processing steps
- we are not interested only in academic publishing but rather improve the situation
- we are also not interested in “owning” this R&D branch, so we are doing everything open source in a website where we are collecting all the material, templates and code

Discussion

(more than “conclusions”)

- every field case revealed unforeseen inconsistencies
- virtually everybody seems interested
- several are interested in our tools[1]

[1] *Everything we do is open source, and available at www.lare4.us*

notes

- importantly, we are planning to do in IFAC WC a workshop where we will propose and discuss together something to share teaching material
- the idea in brief is that flagging teaching material with a strategy like the one presented here may lead to easily searchable information
- this is the first time we are going public with this (very early) announcement
- our primary purpose is to collectively have better material for the students and focus more on being mentors, not parrots that repeat always the same things
- if you are interested please come, you will find the details of how, when and where in the IFAC WC announcements

workshop at Berlin's IFAC WC 2020

on how we may share teaching material

at a whole-community level

notes

- thanks, and please feel free to contact us whenever you want about anything you want

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