Paper Link

Course Prerequisite Networks for Analyzing and Understanding Academic Curricula

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Network Data

Research Mission

Understanding a complex system of relationships between courses is of great importance for the university's educational mission. We study course-prerequisite networks (CPNs), where nodes represent courses and directed links represent the formal prerequisite relationships between them. The main goal of CPNs is to model interactions between courses, represent the flow of knowledge in academic curricula, and serve as a key tool for visualizing, analyzing, and optimizing complex curricula. We show how course-prerequisite networks can be used by students, faculty, and administrators for detecting important courses, improving existing and creating new courses, navigating complex curricula, allocating teaching resources, increasing interdisciplinary interactions between departments, revamping curricula, and enhancing the overall students' learning experience. The proposed methodology is illustrated with a network of courses taught at the California Institute of Technology.

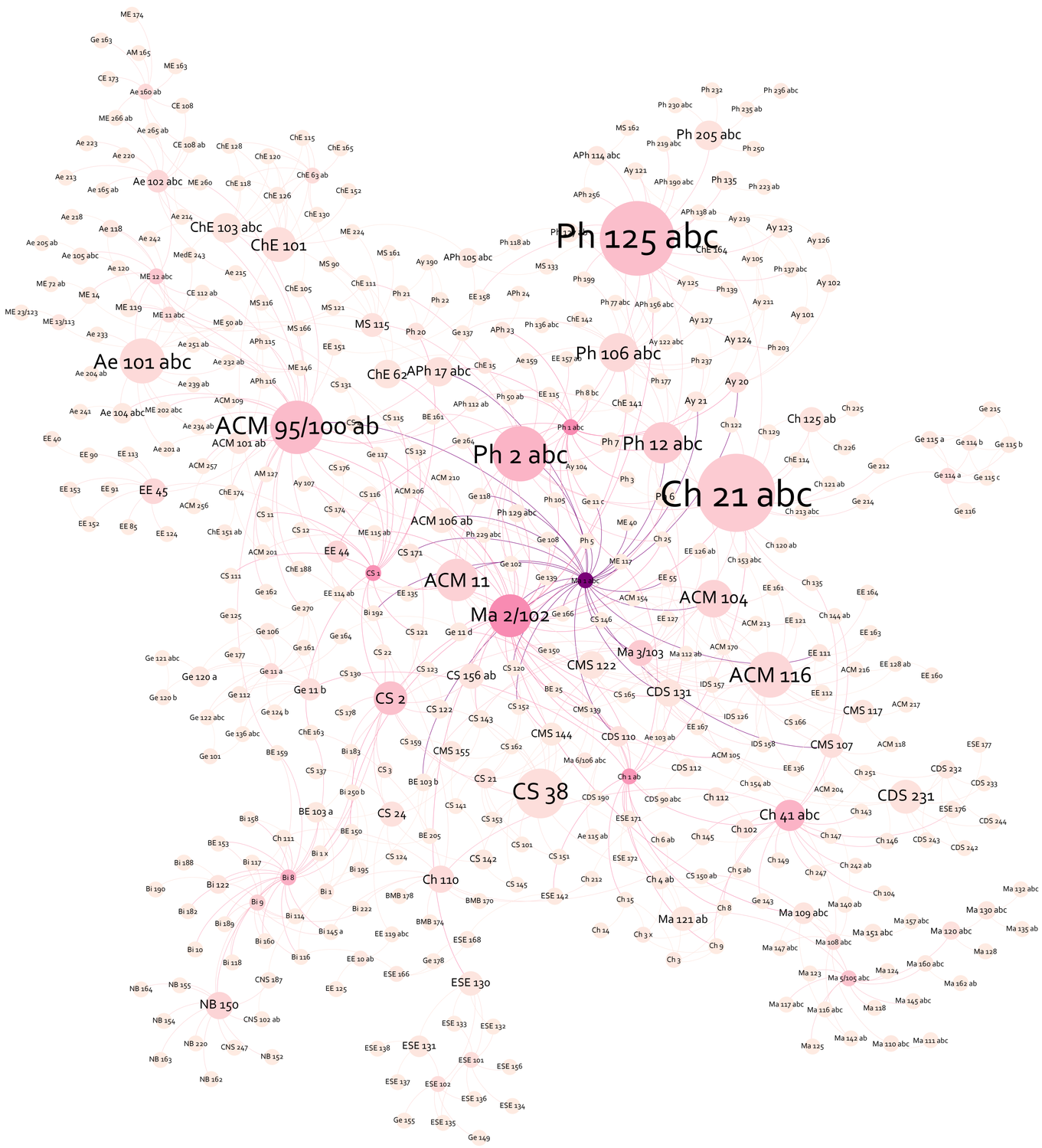
Interdependence Analysis

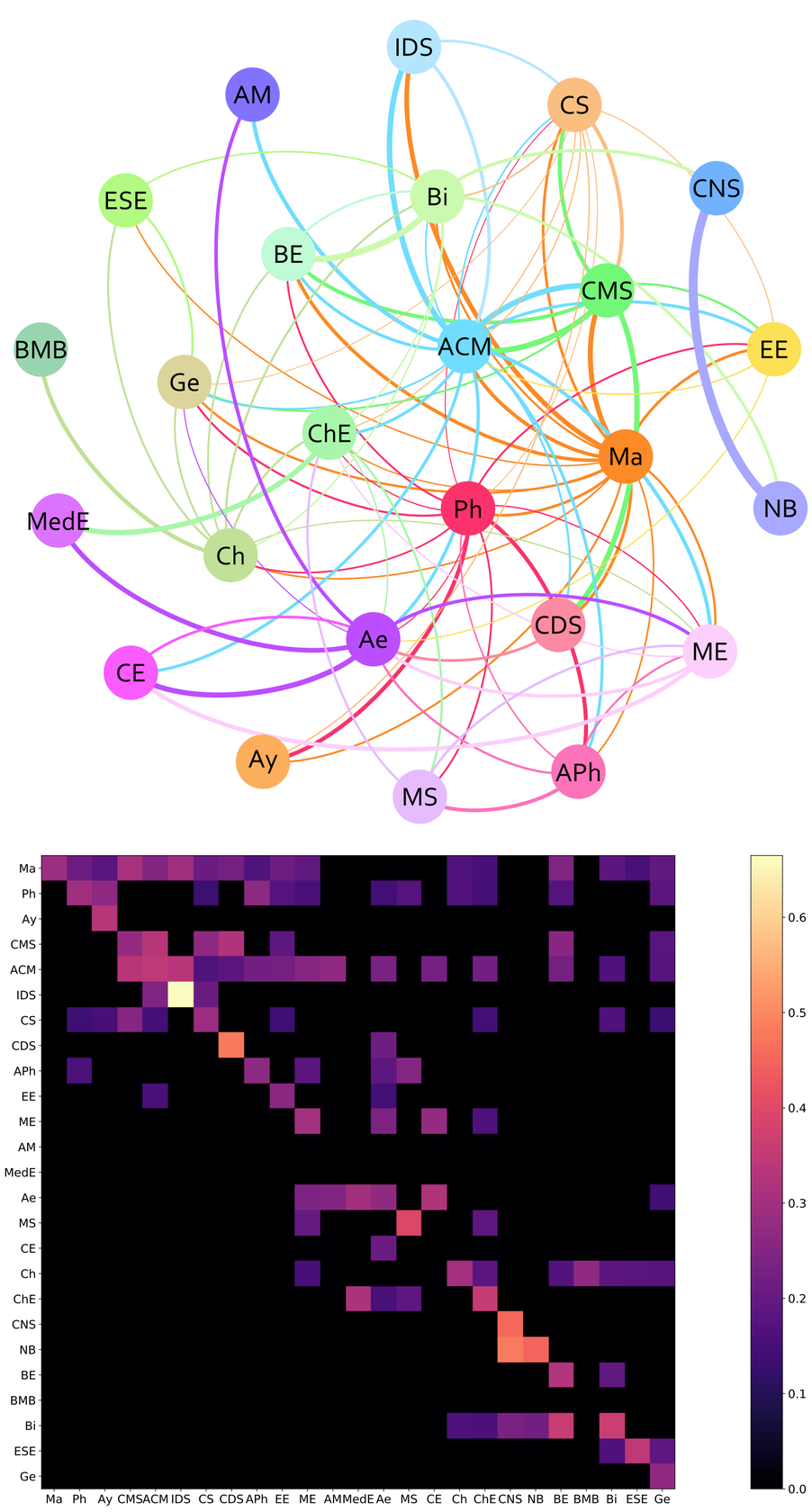
Let $\mathcal{A}$ be the set of all areas of study within the university. Let $\mathcal{C}_a \subset \mathcal{G}$ be the set of all courses in area $a \in \mathcal{A}$. Furthermore, let $\mathcal{C}_a^+$ be the multiset of all postrequisites of $\mathcal{C}_a$. Finally, let $\mathcal{C}_{aa'}^+ \subset \mathcal{C}_a^+$ be a multisubset consisting of courses in $\mathcal{C}_a^+$ whose area of study is $a' \in \mathcal{A}$. To measure the dependence of area a' on a, we define:

$$R_{aa'}^{\mathcal{A}} = \left(-\log \frac{|\mathcal{C}_{aa'}^+|}{|\mathcal{C}_a||\mathcal{C}_{a'}|} \right)^{-1} = \left(-\log \frac{\sum_{i,j \in \mathcal{G}} A_{ij} \delta(a_i, a) \delta(a_j, a')}{\sum_{i \in \mathcal{G}} \delta(a_i, a) \sum_{j \in \mathcal{G}} \delta(a_j, a')} \right)^{-1}$$

Centrality Measures

- **In-degree:** measures how *specialized* a course is
- **Out-degree:** measures how *fundamental* a course is
- **PagreRank:** measures how fundamental a course is and favors more *introductory* courses
- **Betweenness:** identifies intermediate-level courses that *bridge* less and more advanced courses





Most Important Courses

	PageRank	Betweenness	Out-Degree
1	Freshman Math	Physical Chemistry	Differential Equations
2	Differential Equations	Quantum Mechanics	Methods of Applied Mathematics
3	Freshman Physics	Sophomore Physics	Freshman Math
4	Intro to Programming	Methods of Applied Mathematics	Molecular Biology
5	Freshman Chemistry	Algorithms	Intro to Probability
6	Molecular Biology	Probability Models	Sophomore Physics
7	Organic Chemistry	Differential Equations	Quantum Mechanics
8	Sophomore Physics	Intro to Computational Science	Organic Chemistry
9	Methods of Applied Mathematics	Analytical Sophomore Physics	Freshman Physics
10	Quantum Mechanics	Classical Physics	Probability Models
11	Data Structures & Algorithms	Applied Linear Algebra	Freshman Chemistry
12	Intro to Abstract Algebra	Fluid Mechanics	Intro to Programming

Most Important Areas of Study

	Out-Degree	PageRank	Betweenness
1	Math	Math	Biology
2	ACM	ACM	ACM
3	Physics	CS	Aerospace
4	CS	Physics	Chem Eng.
5	Chemistry	CMS	Chemistry

Summary

To summarize, a CPN is an indispensable tool for summarizing, visualizing, and analyzing an academic curriculum. It can help to better understand and revamp the curriculum, detect important courses, improve existing and create new courses, meaningfully allocate teaching resources, increase interdisciplinary interactions between various university units, and enhance the overall student learning experience.

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