Pathways to solve an estimation problem


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Can we find patterns in the strategies students follow to solve estimation problems? Do students' educational backgrounds affect their choice of strategy?

Ill-structred problems: estimation

The strategy for solving ill-structured problems is often unclear. The solver must begin by identifying the parameters that are required to obtain an answer. Estimation problems involve determining relationships between known and unknown quantities, making simplifications, combining assumptions and ideas, and breaking down the problem into smaller problems. A standard technique used to solve ill-defined problems such as estimation problems is to make subjective assumptions that can make the problem more defined, limit the size of solution space, and turn it into a better-defined problem (Reitman, 1964). Generally, there are multiple pathways to reach an answer.

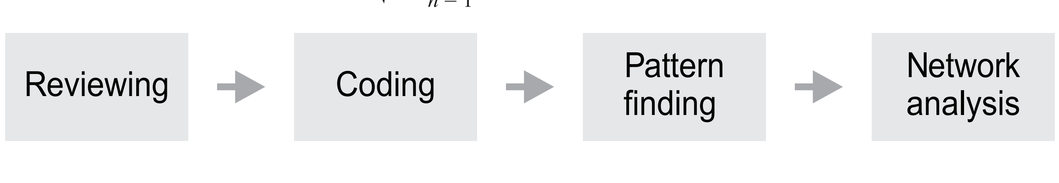
Sample problem

"In an effort to cover all four years of her private university tuition, books, and living expenses, Penny, friends of Leonard and Sheldon, decides to collect soda cans from people's trash and redeem deposits. Will Penny need to take out a loan for her college education?"

Method

We asked 86 undergraduate students enrolled in an introductory physics course to solve estimation problems, articulating their thought process. We recorded five variables: the major (engineering = 1; non-engineering = 0), the level of completed physics and calculus courses (none = 0; high school = 1; advanced = 2), and the students' learning style. For every variable, we calculated a normalized value, and then we defined the similarity S(i,j) between node i and j as the geometric mean of these normalized values. With similarity metrics, we used the so-called "Louvain method" (Blondel et al, 2008) to detect clusters connected densely and the "Force Atlas" method (Bastian et al, 2009) to draw network graphs.

$$S(i,j) = \sqrt{\frac{1}{5}\sum_{n=1}^{5}\left(\frac{x_{ni}-x_{nj}}{\max_k x_{nk}-\min_k x_{nk}}\right)^2}$$



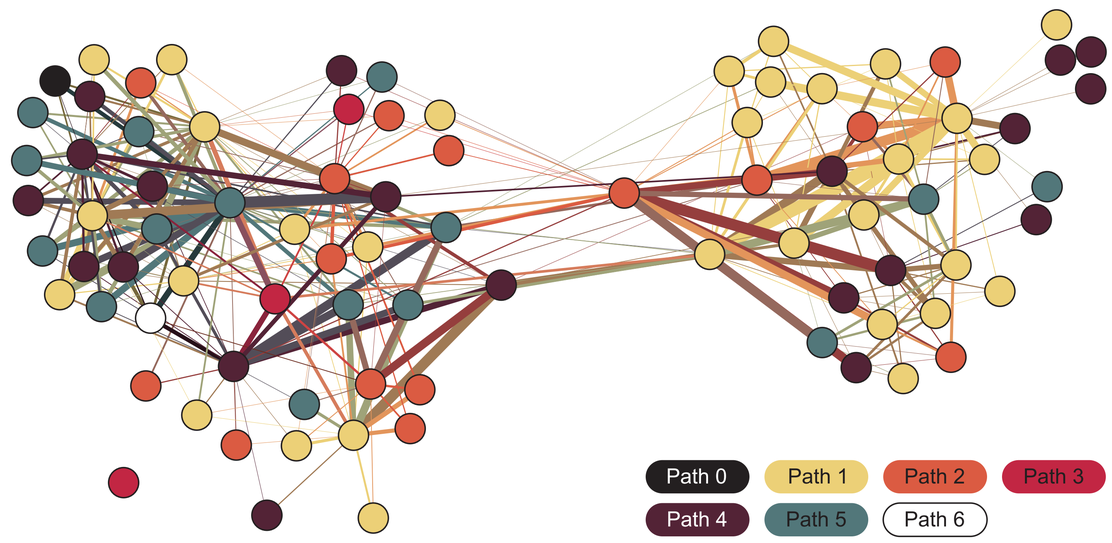
Solution pathway patterns

By analyzing the students' recorded solutions, we identified five distinct solution pathways (see Table). Paths 1 and 2 start from a (known) tuition fee to obtain either the number of cans or time required for collection; Paths 3,4, and 5 start by making assumptions, and then doing a "cost-revenue" comparison. The first group decides on the answer based on whether or not the obtained value is reasonable or not, whereas the second group decides by comparing cost and revenue.

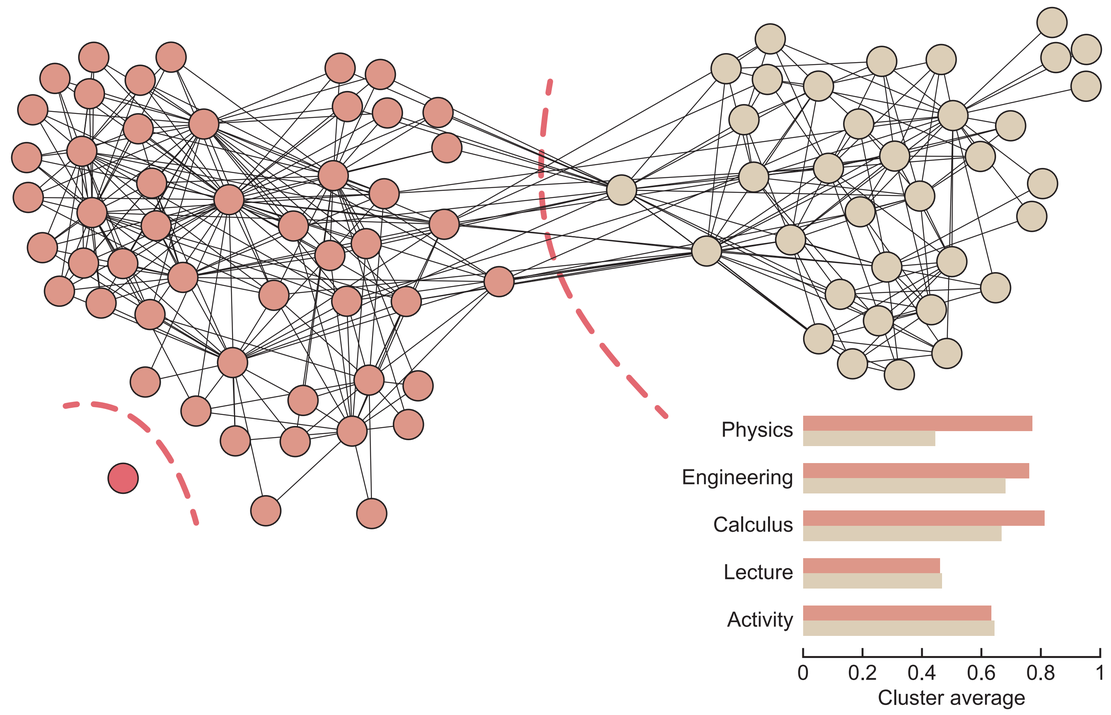
Path	Students	Decision	Constraints	Assumptions
0	1	–	–	1
1	31	How many cans	Dollar per can	2.74
2	15	How much time	Dollar per can	3.33
3	3	Cost and revenue	Dollar per can, Time, People	4.33
4	20	Cost and revenue	Dollar per can, Time, Speed	4.3
5	15	Cost and revenue	Dollar per can, Time, Speed, Distance, People	5.06
6	1	–	–	3

Educational backgrounds and pathways

The community detection algorithm (Blondel et al, 2008) splits the network into two densely connected sub networks (see Figure) and there is a tendency for the left community to predominantly choose Path 5, while the right community appears to prefer Path 1.



Our analysis also shows that the left community has more engineering student than the right community.



Conclusion

We show network analysis can be used to analyze solution pathways for solving estimation problems. Our analysis shows that students who pursue engineering careers and who have more experience in physics and calculus, tend to start their solutions by making assumptions and break the problem into smaller pieces.