COM2031 Advanced Algorithms, Autumn Semester 2019

Lab 10: Open Pit Mining: More Applications of Network Flow

Purpose of the lab

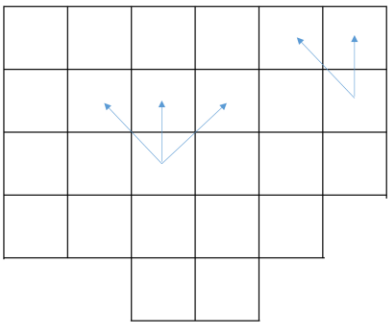
This week's lab is to explore a further application of Network Flow, this time applied to optimal strategies for open pit mining.

Wikipedia defines Open Pit mining as: "*a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit*". In other words, excavation from the surface.

Here is a picture of the large open-pit Twin Creeks gold mine in Nevada, United States. (Picture courtesy of Geomartin, https://commons.wikimedia.org/wiki/File:Twincreeksblast.jpg)

If it is known (through geological techniques) where there are items to dig for, then the problem is to optimise where to dig in order to make the maximum profit (from the value of what is excavated) against the cost of digging.

We model the mine as a number of layers, where each layer is made up of blocks, and to excavate a block some of the blocks in the layer above must first be excavated, as in the following diagram:



A block must first have the block directly above, and diagonally above to the left and to the right. (We are assuming a 2-D mine in this lab but the same principle works in 3D)

Blocks either have a net cost to be excavated (if they do not contain much of value), or a net profit (if they do contain items of value). Hence each block has a positive or negative profit associated with it. For example, the following example is taken from [1]:

1	−2	−2	−2	−2
	5	6	−3	
		4		

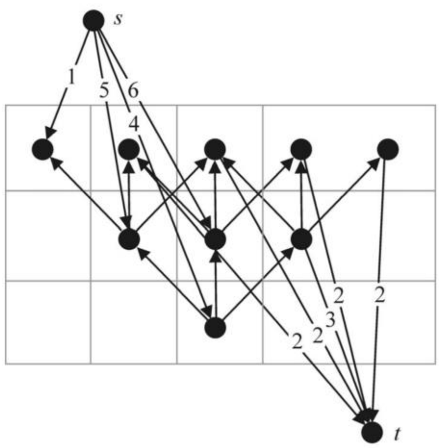
The Open Pit mining problem is: which blocks should be excavated to maximise profit?

This problem can be modelled as a Max Flow / Min Cut problem. It can be thought of as similar to the **Project Selection** problem from Lab 9, where projects have profit or cost, and there are dependencies between projects.

In this case the blocks have profit or cost, and the dependencies are between a block b and the blocks in the level above that must be mined in order to mine b.

Then the Open Pit mining problem can be formulated as the problem of which blocks to select in order to maximise profit.

In the case of the example above, this is turned into the following flow graph:



The source s is introduced and linked to every positive node, with a capacity corresponding to the profit on the node.

The sink t is introduced and every negative node is linked to t with a capacity corresponding to the negation of the cost (note that this is positive, since the cost is a negative value).

All dependencies are also included as flows with infinite (i.e. as large as we like) capacity.

Use the Ford-Fulkerson tool from Lab 9 to model and solve the following problems:

Question 1: What are the optimal blocks to mine in the above example?

Question 2: What are the best blocks to mine in the following example?

– 1	– 2	– 2	– 2	– 2
	2	– 4	7	
		6		

Question 3: What is the optimal mine in the following example?

-1	-1	-1	-1	-1	-1
-2	-3	2	-3	-2	-3
-3	-2	5	6	-4	-4
-9	-4	7	-1	6	

Question 4: What is the optimal mine in the following example – the same as the previous question except with two additional blocks in the fifth layer down?

-1	-1	-1	-1	-1	-1
-2	-3	2	-3	-2	-3
-3	-2	5	6	-4	-4
-9	-4	7	-1	6	
		6	8		

References

[1] Optimized Open Pit Mine Design, Pushbacks and the Gap Problem—A Review C. Meaghera, R. Dimitrakopoulosa, and D. Avisa, Journal of Mining Science, 2014, Vol. 50, No. 3.