Algorithm Theory

Chapter 6
Graph Algorithms

Part VII:
Matrix Rounding

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Matrix Rounding

- **Given:** $p \times q$ matrix $D = \{d_{i,j}\}$ of real numbers
- **row i sum:** $a_i = \sum_j d_{i,j}$, **column j sum:** $b_j = \sum_i d_{i,j}$
- **Goal:** Round each $d_{i,j}$, as well as a_i and b_j up or down to the next integer so that the sum of rounded elements in each row (column) equals the rounded row (column) sum
- **Original application:** publishing census data

Example:

3.14	6.80	7.30	17.24
9.60	2.40	0.70	12.70
3.60	1.20	6.50	11.30
16.34	10.40	14.50	

original data

3	7	7	17
10	2	1	13
3	1	7	11
16	10	15	

possible rounding

Matrix Rounding

Theorem: For any matrix, there exists a feasible rounding.

Remark: Just rounding to the nearest integer doesn't work

0.35	0.35	0.35	1.05
0.55	0.55	0.55	1.65
0.90	0.90	0.90	

original data

0	0	0	0
1	1	1	3
1	1	1	

rounding to nearest integer

0	0	1	1
1	1	0	2
1	1	1	

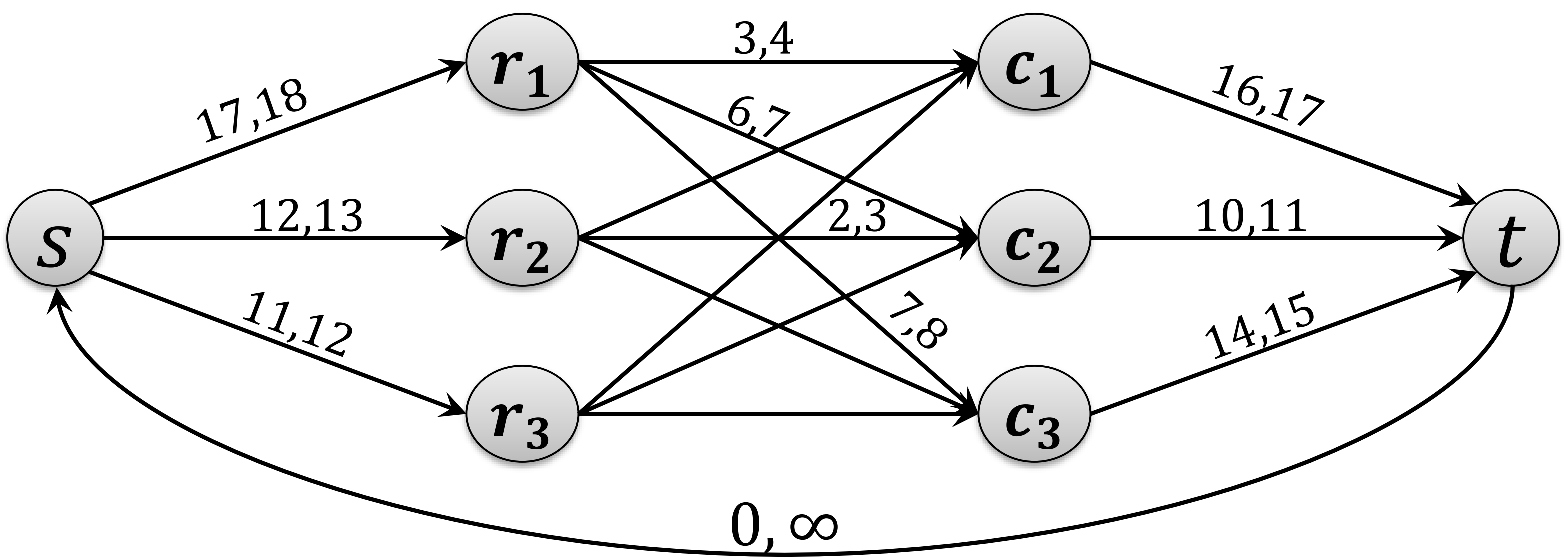
feasible rounding

Reduction to Circulation

3.14	**6.80**	**7.30**	**17.24**
9.60	**2.40**	**0.70**	**12.70**
3.60	**1.20**	**6.50**	**11.30**
16.34	**10.40**	**14.50**	

Matrix elements and row/column sums give a feasible circulation that satisfies all lower bound, capacity, and demand constraints

rows: **columns:**



all demands $d_v = 0$

Matrix Rounding

Theorem: For any matrix, there exists a feasible rounding.

Proof:

- The matrix entries $d_{i,j}$ and the row and column sums a_i and b_j give a feasible circulation for the constructed network

- Every feasible circulation gives matrix entries with corresponding row and column sums (follows from demand constraints)

- Because all demands, capacities, and flow lower bounds are integral, there is an integral solution to the circulation problem

  → gives a feasible rounding!