

Long Title

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Introduction

Simple List

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- ▶ Item.

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 - * Sub Item.

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Image



UNIVERSITY

Alignment 1

$$\sum_{i,j}^n \mathbb{E}_{i,j} = \sum_{i,j \neq i}^n \mathbb{E}_{i,j} + \sum_i^n \mathbb{E}_{i,i}$$

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$$\begin{aligned}\sum_{i,j}^n \mathbb{E}_{i,j} &= \sum_{i,j \neq i}^n \mathbb{E}_{i,j} + \sum_i^n \mathbb{E}_{i,i} \\ &= \sum_{i,j \neq i}^n \frac{k_i k_j}{s-1} + \sum_i^n \frac{k_i(k_i-1)}{s-1}\end{aligned}$$

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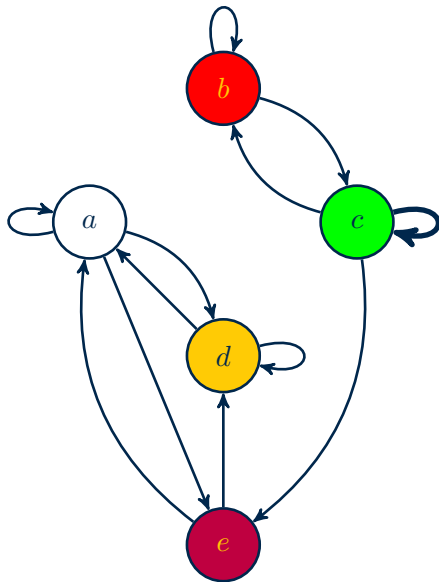
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$$Q = \frac{1}{s} \left[\sum_{i,j \neq i}^n \left(A_{i,j} - \frac{k_i k_j}{s-1} \right) \delta(c_i, c_j) + \sum_i^n \left(A_{i,i} - \frac{k_i(k_i-1)}{s-1} \right) \right].$$

Algorithms



Matrix

| \vec{A} | a | b | c | d | e |
|-----------|-----|-----|-----|-----|-----|
| a | 1 | 0 | 0 | 1 | 1 |
| b | 0 | 1 | 1 | 0 | 0 |
| c | 0 | 1 | 2 | 0 | 1 |
| d | 1 | 0 | 0 | 1 | 0 |
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The adjacency matrix is the expected form computers will store networks in.

Colored Table

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| <i>merge</i> | $\partial \vec{Q}_i$ | $\partial \vec{Q}_j$ | $\partial \vec{Q}_{i'}$ | $\Delta \vec{Q}$ |
|--------------|----------------------|----------------------|-------------------------|------------------|
| $\{a, d\}$ | 4/13 | 7/13 | 22/13 | 11/169 |
| $\{a, e\}$ | 4/13 | -4/13 | 14/13 | 14/169 |
| $\{b, c\}$ | 9/13 | 14/13 | 35/13 | 12/169 |
| $\{c, e\}$ | 14/13 | -4/13 | 9/13 | -1/169 |
| $\{d, e\}$ | 7/13 | -4/13 | 6/13 | 3/169 |

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The best merge for nodes a , and e , is to merge them together, similarly, the best for b , and c , is to merge them together, last, the best merge for d is to merge it with a .

Conclusion

We truly covered a lot, and yet this is only a glimpse.

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QUESTIONS?

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References [1/4]

- [1] Arenas, A., Fernández, A., and Gómez, S. Analysis of the structure of complex networks at different resolution levels. *New Journal of Physics* 10, 5 (May 2008).
- [2] Barabási, A. L. *Network Science*. Cambridge University Press, 2016.
- [3] Blondel, V. D., Guillaume, J.-L., Lambiotte, R., and Lefebvre, E. Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment* (Oct. 2008).
- [4] Dugué, N., and Perez, A. Directed Louvain : maximizing modularity in directed networks. Research report, Université d'Orléans, Nov. 2015.
- [5] Girvan, M., and Newman, M. E. J. Community structure in social and biological networks. *Proceedings of the National Academy of Sciences* 99, 12 (2002), 7821–7826.