Computational and Systems Biology

Food-bridging: a new network construction to unveil the principles of cooking

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Food pairing and food bridging

- **Food pairing**
  - Measured by the number of flavours a pair of ingredients share
  - Average number of shared flavours in the recipe

- **Food bridging**
  - If there exists an alternative indirect path between two ingredients that is stronger than the direct connection, then they may become affine through a chain of ingredients

Roadmap

01 Construct the Flavour Network

02 Construct the metric and semi-metric backbone

03 Calculate the food pairing and food bridging

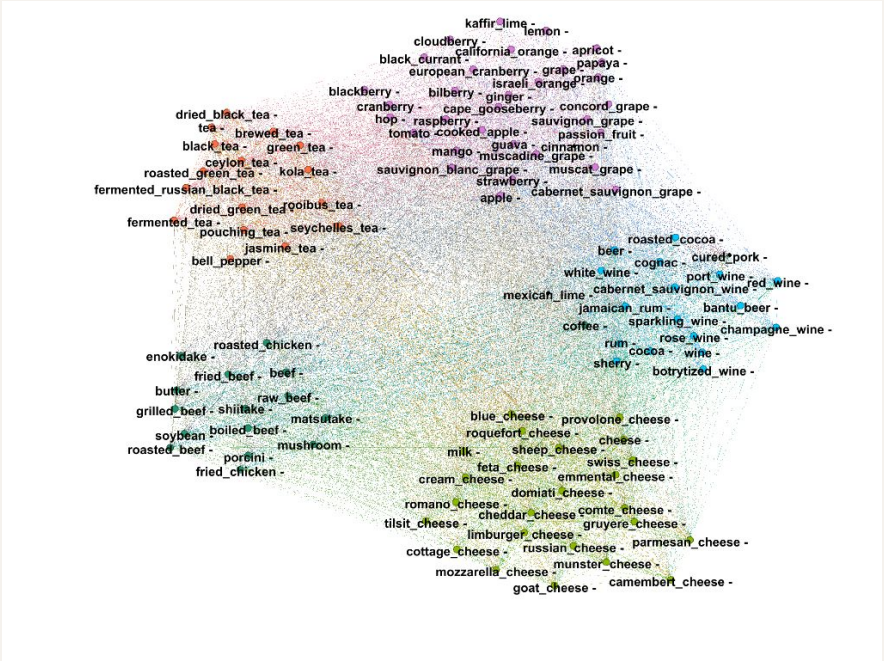
04 Analyse and classify cuisines

Flavour Network visualisation:

- **Nodes:** Ingredients
- **Edges:** compounds shared between two ingredients and
- **Weights** are indicative of the number of the compounds two ingredients share.

In total, there are 1507 nodes and 2,21,777 edges.

Flavor network as visualized in Gephi, top 107 nodes on basis of degree centrality and colour-coded according to communities. →

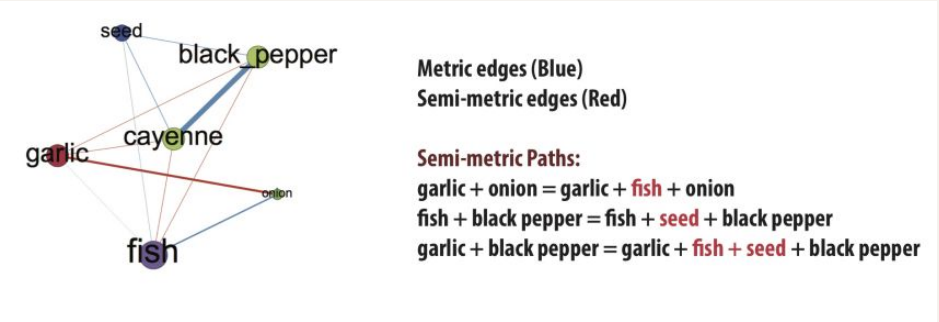


Recipe-Ingredient Data

- The recipe-ingredient dataset had recipes from different cuisines and the ingredients used in them.
- The dataset had a total of **56,498** recipes
- We performed analysis on a subset of these recipes.
- Fo our analysis we selected **30 recipes from each of the seven cuisines**: East Asian, Southeast Asian, North American, Latin American, Eastern European, Western European, Southern European
- Subgraph of edges consisting of all unique ingredients of the selected recipes is formed from the original flavor network: 216 nodes 14,698 edges

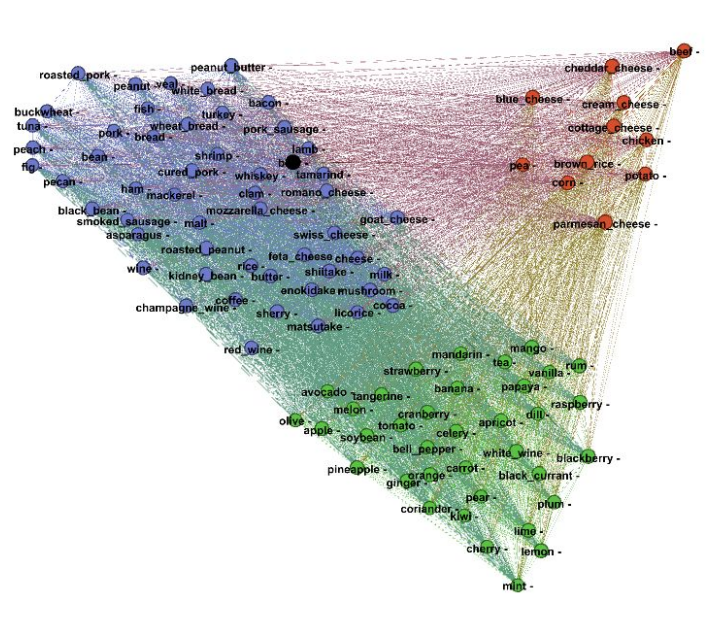
Metric and Semi-Metric edges

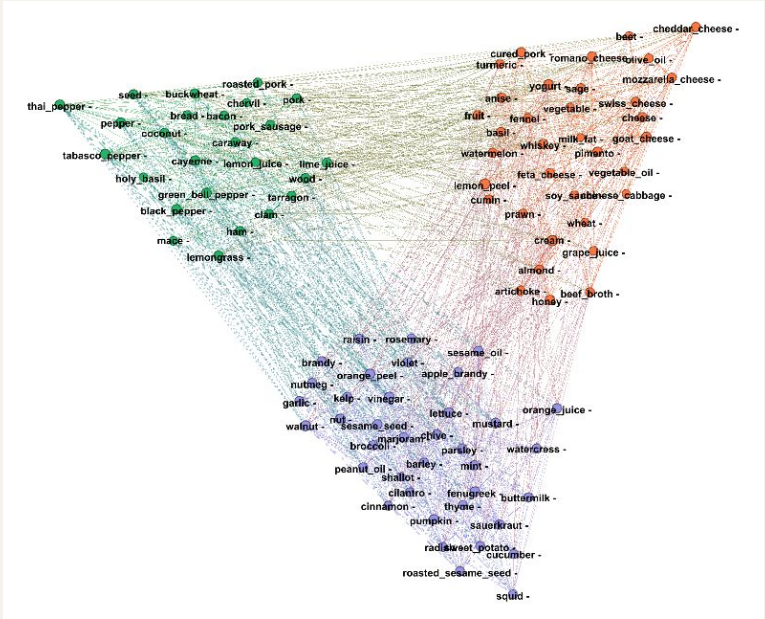
Metric edges: the **strongest path** between two nodes **is the edge itself** (direct path)	**Semi-metric edges**: the **strongest path** between two nodes **is an alternative path and not the direct edge itself**(indirect path)



Here, due to hardware limitation, 10 shortest paths (excluding the direct edge) between two nodes are extracted and compared with the direct edge instead of all the existing paths.

Metric and Semi-metric backbone





Backbone of **top 100 nodes** based on degree centrality and colour-coded according to communities detected using the Louvain method based Modularity calculation in Gephi.

(a) Metric backbone (193 nodes, 11,231 edges) (b) Semi-Metric backbone (214 nodes, 3467 edges)

Average food pairing and food bridging

- The food pairing value of a recipe is defined as follows:

$$N_s(R) = 2 \times \frac{\sum_{i,j\ i \neq j} |C_i \cap C_j|}{n_r(n_r - 1)}$$

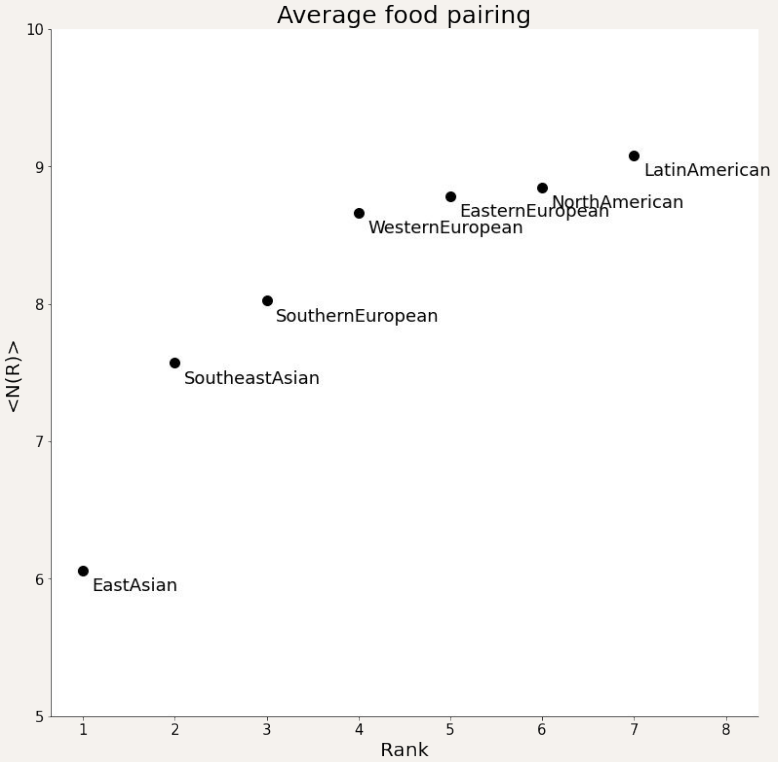
Where, n_r corresponds to the number of ingredients in a recipe, where as C_k denotes the edge weight between the pair of ingredients in the flavour network.

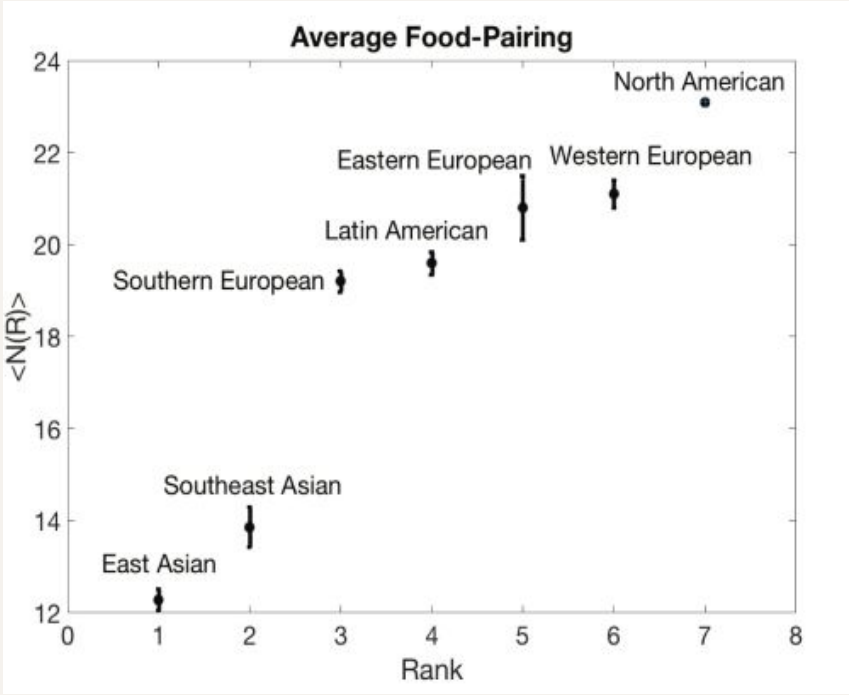
- Further we take a simple average of the food pairing values of different recipes in a cuisine to get the average food pairing number of the cuisine.

- The semi-metric percentage that is used to compare the food bridging aspect of cuisines is calculated by taking the percentage of number of semi metric edges out of the total edges present.

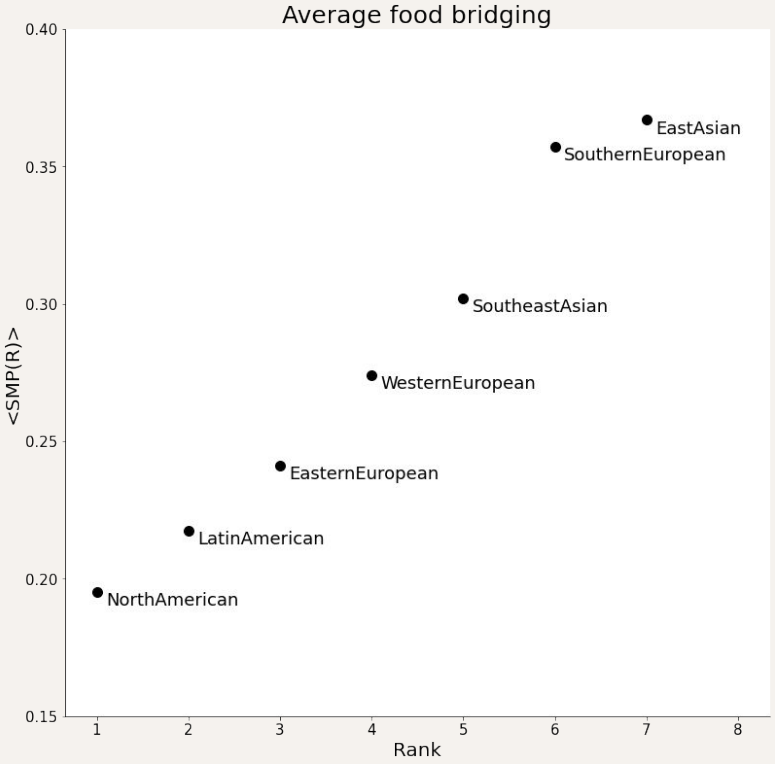
$$SMP(R) = \frac{\text{Total semi-metric edges in a recipe}}{\text{Total edges between ingredients of the recipe}}$$

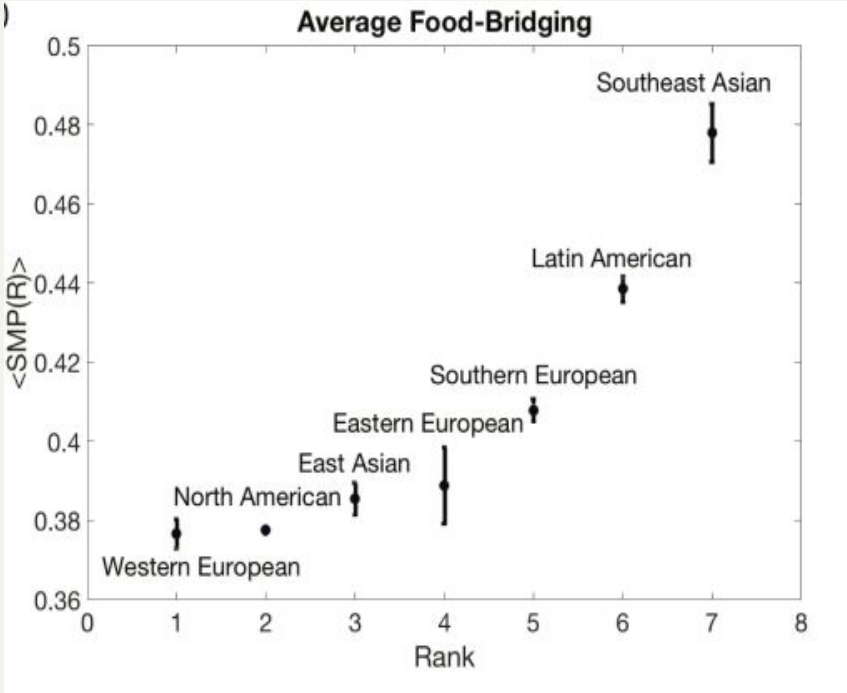
Results


Average food pairing
<N(R)>
Rank
LatinAmerican
NorthAmerican
EasternEuropean
WesternEuropean
SouthernEuropean
SoutheastAsian
EastAsian

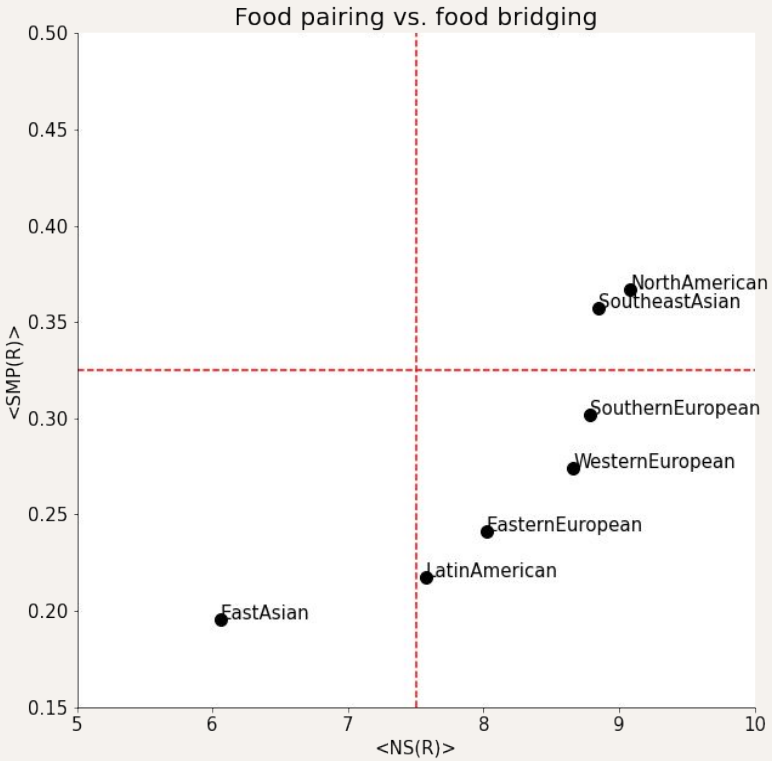

Average Food-Pairing
<N(R)>
Rank
North American
Eastern European
Western European
Latin American
Southern European
Southeast Asian
East Asian

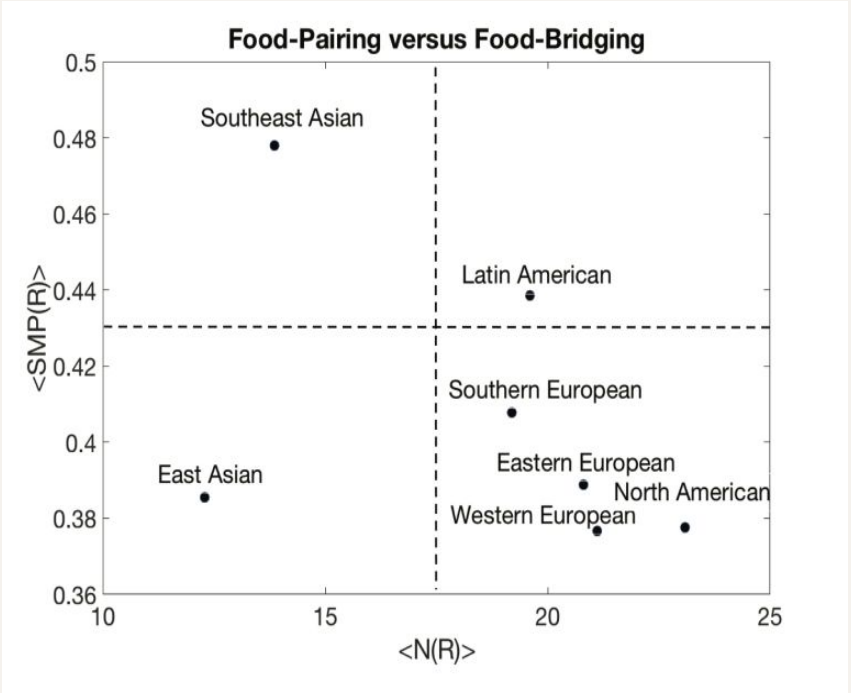
Results


Average food bridging
<SMP(R)>
Rank
EastAsian
SouthernEuropean
SoutheastAsian
WesternEuropean
EasternEuropean
LatinAmerican
NorthAmerican

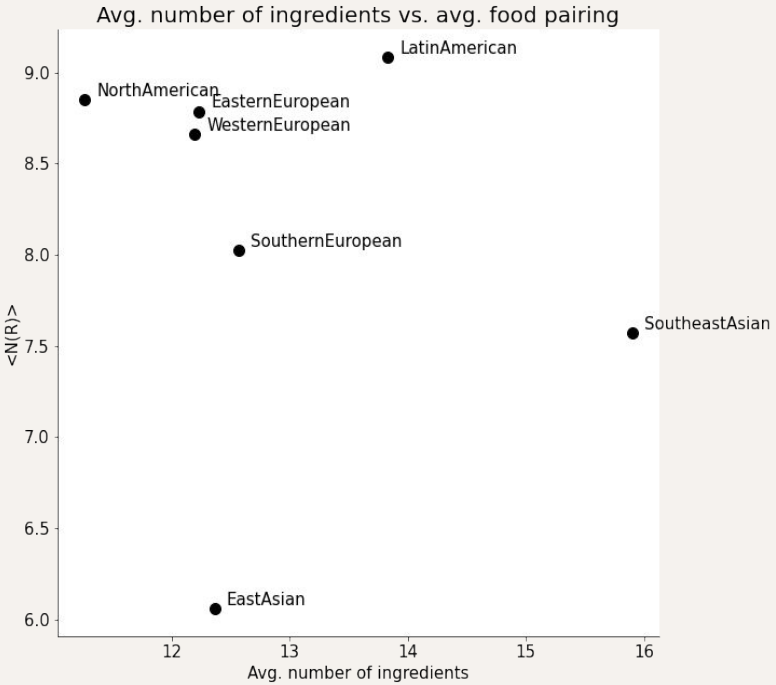

Average Food-Bridging
<SMP(R)>
Rank
Southeast Asian
Latin American
Southern European
Eastern European
East Asian
North American
Western European

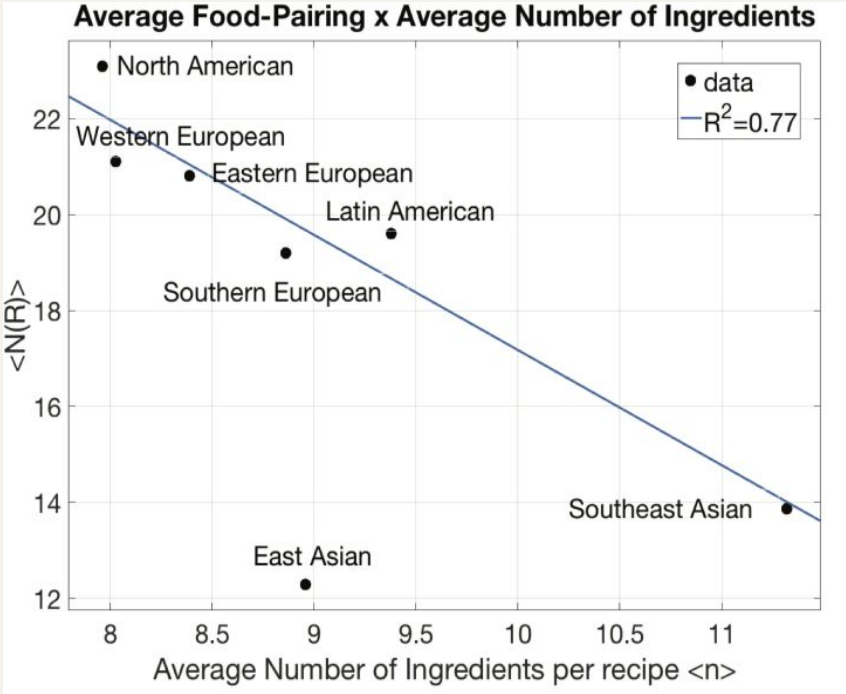
Results


Food pairing vs. food bridging
<SMP(R)>
<NS(R)>
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
5
6
7
8
9
10
NorthAmerican
SoutheastAsian
SouthernEuropean
WesternEuropean
EasternEuropean
LatinAmerican
EastAsian

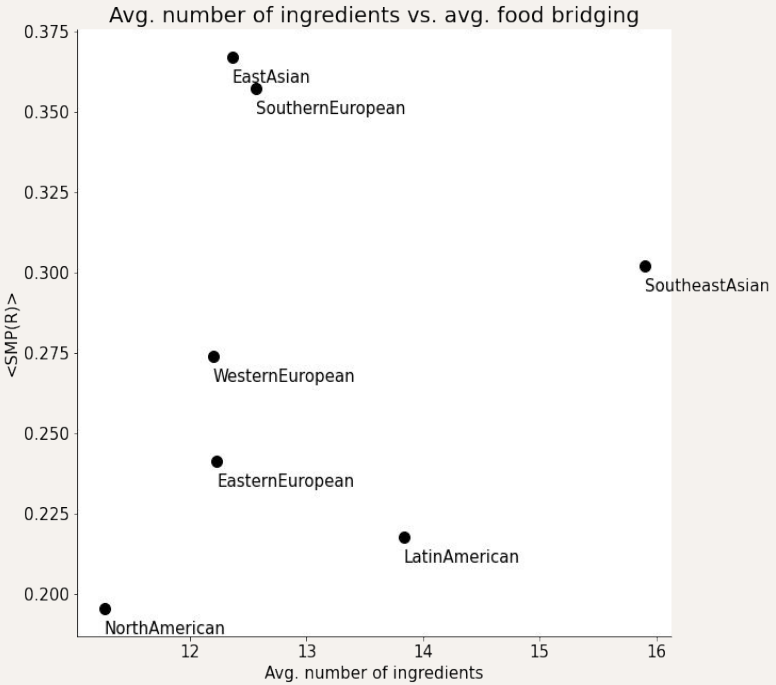

Food-Pairing versus Food-Bridging
<SMP(R)>
<N(R)>
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
10
15
20
25
Southeast Asian
Latin American
Southern European
Eastern European
North American
Western European
East Asian

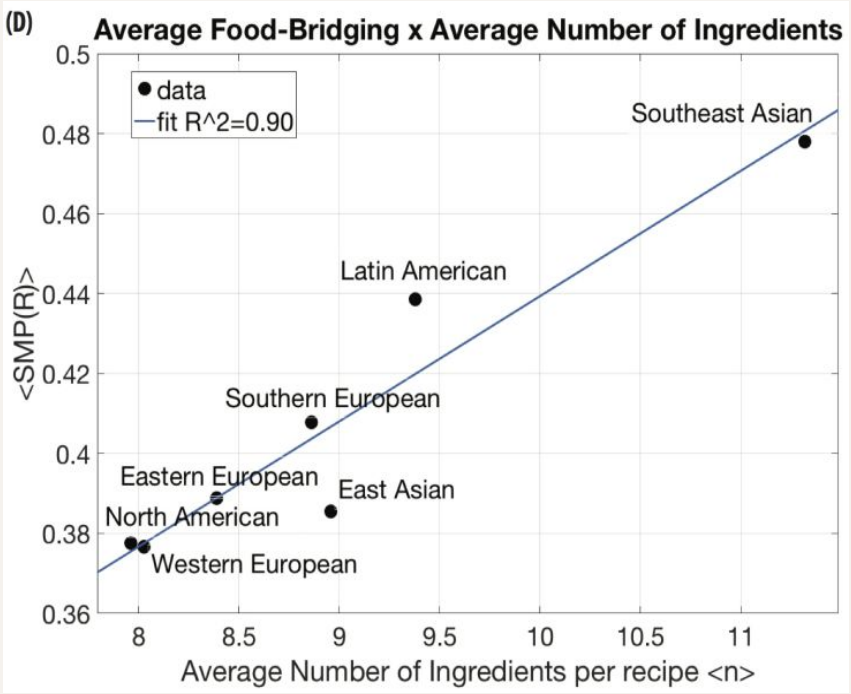
Results


Avg. number of ingredients vs. avg. food pairing
LatinAmerican
NorthAmerican
EasternEuropean
WesternEuropean
SouthernEuropean
SoutheastAsian
EastAsian
<N(R)>
Avg. number of ingredients
9.0
8.5
8.0
7.5
7.0
6.5
6.0
12
13
14
15
16


Average Food-Pairing x Average Number of Ingredients
North American
Western European
Eastern European
Latin American
Southern European
Southeast Asian
East Asian
data
R^2=0.77
<N(R)>
Average Number of Ingredients per recipe <n>
22
20
18
16
14
12
8
8.5
9
9.5
10
10.5
11

Results


Avg. number of ingredients vs. avg. food bridging
<SMP(R)>
Avg. number of ingredients
EastAsian
SouthernEuropean
SoutheastAsian
WesternEuropean
EasternEuropean
LatinAmerican
NorthAmerican
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
12
13
14
15
16


(D)
Average Food-Bridging x Average Number of Ingredients
data
fit R^2=0.90
<SMP(R)>
Average Number of Ingredients per recipe <n>
Southeast Asian
Latin American
Southern European
Eastern European
East Asian
North American
Western European
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
8
8.5
9
9.5
10
10.5
11

Conclusion

- The results reproduced by us do not completely coincide with the ones produced by the authors in the research paper.
- This happens because of the fact that we have considered a small sub-graph of the entire flavour network (by picking 30 recipes from each cuisine) while the authors consider all the recipes for each cuisine.
- Owing to the computational intensity of the problem, we had to restrict ourselves to analyse the 10 shortest paths between any two nodes only for calculating the metric and semi-metric edges. Some amount of error is introduced due to the same (false metric edges would have been detected).

References

- Simas, Tiago & Ficek, Michal & Diaz-Guilera, Albert & Obrador, Pere & Rodriguez, Pablo, "Food-Bridging: A New Network Construction to Unveil the Principles of Cooking", Frontiers in ICT (2017)
- Y-Y. Ahn, S.E. Ahnert, J. P. Bagrow, and A-L. Barabasi "Flavor network and the principles of food pairing", Scientific Reports 1:196 (2011)
- Dataset: https://yongyeol.com/2011/12/15/paper-flavor-network.html

Thank you