Using phylogenetic methods to explore culinary innovations in culture

Introduction

The ability of phylogenetic methods to build maps of relatedness based on morphological states can be exploited to understand the transmission of cultural knowledge. In the research following, phylogenetic methods were tested first to see if they had power to accurately cluster data on culinary innovations found in recipes to their country of origin. The clustering of various phylogenetic methods were attempted to assess the most suitable method. The resultant best clustering was then used to assess potential relations between culinary innovations.

While using phylogenetic methods to test relatedness between cultural aspects is not a new idea as shown between building language trees and music trees [1-3], the full potential of this concept has yet to be exploited. Cultural innovations are passed down through generations within a populace. Cultures have been able to maintain development in relative isolation bar their near neighbors until the invention of modern modes of travel. Horizontal transmission of cultural elements have been relatively slow even during the age of ship travel. As the world becomes more connected through air travel by the use of airplane, and we continue to move towards a global economy, cultures are beginning to merge into a continuum. It can be expected that in the near future, cultural elements may become merged to the point where no distinct signal of cultural origin can be distinguished without extensive look to the past, highlighting the importance of this work.

Methods

Assembling the dataset

The top 20 recipes from a set of countries/regions were scrapped from AllRecipes.com using a public script that had been repurposed by Dr. Jennifer Chang (https://github.com/j23414/allrecipes). The data scraped from the page included recipe country/region, recipe id, recipe title, and recipe ingredients. The ingredients were used as the characters for phylogenetic reconstruction. The recipes did have a degree of redundancy to them, with multiple recipes for the same dish with slight variations being found. These repetitions were not controlled for. This data was further processed to be in a format where the characters were presented in a binary manner. This file was processed into Tree analysis using New Technology (TNT) format, phylip, and nexus format for use with different tools downstream in the analysis. In total, 356 recipes were used, composed of a total of 223 ingredients.

Inferring relatedness by parsimony methods

The characters of each recipe were defined as discrete and binary. TNT was used to analyze the characters (see recipes.tnt in the data folder). TNT was set to hold 1000 trees for swapping, and performed random addition of sequences with tree rearrangements in 200 replicates. A majority consensus tree was attempted to be built, though was of low quality containing many polytomies. A single tree with the best score (1712) was used for comparison [5].

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Distance methods

Pairwise distances between recipes were calculated by summing the results of an exclusive or (XOR) between binary characters. If one recipe had an ingredient that was not present in the compared recipe, the distance between recipes was incremented by one. Trees were built using neighbor-joining methods, made available through the APE package in R[6]. Code is available in the repository (njTree.R).

Maximum likelihood methods

Maximum likelihood trees were built using RAxML under a general time reversible (GTR) model for the multi-state morphological data[7]. Additional bootstrapping was not performed to keep the branch lengths meaningful in a sense of likelihood rather than bootstrap support values. In genetic phylogenies, the branch length may refer to the number of substitutions per site. In this context, it should be representative of the ingredient substitutions.

```
raxmlHPC-PTHREADS-SSE3 -p 777 -m MULTIGAMMA -s test.phy -n maxlikefood
```

Bayesian methods

Bayesian analysis were run on the hpc cluster using mrbayes[8]. The likelihood coding model was set to variable sampling due to morphological features of variance being selected (ingredients per recipe). The Dirichlet prior was set to infinity to assume all character states had equal frequency, and the site specific rate models was set to variable, although the data had a single partition of, which the program would have assumed an average rate of substitution being 1. After 10,000,000 generations sampling every 1000 trees, runs on two chains, the analyses failed to converge. There was an observed lack of swapping between hot and cold chains, potentially contributing to the failure to converge. Single high scoring trees in the upper part of tree space were comparable to the maximum likelihood trees and were used for comparison. Files related to the Bayesian run are available in the repository.

Rendering Trees

All trees were drawn with FigTree version 1.4.3[4]. All trees were rooted to the recipe “Lamb Tagine” of African origin.

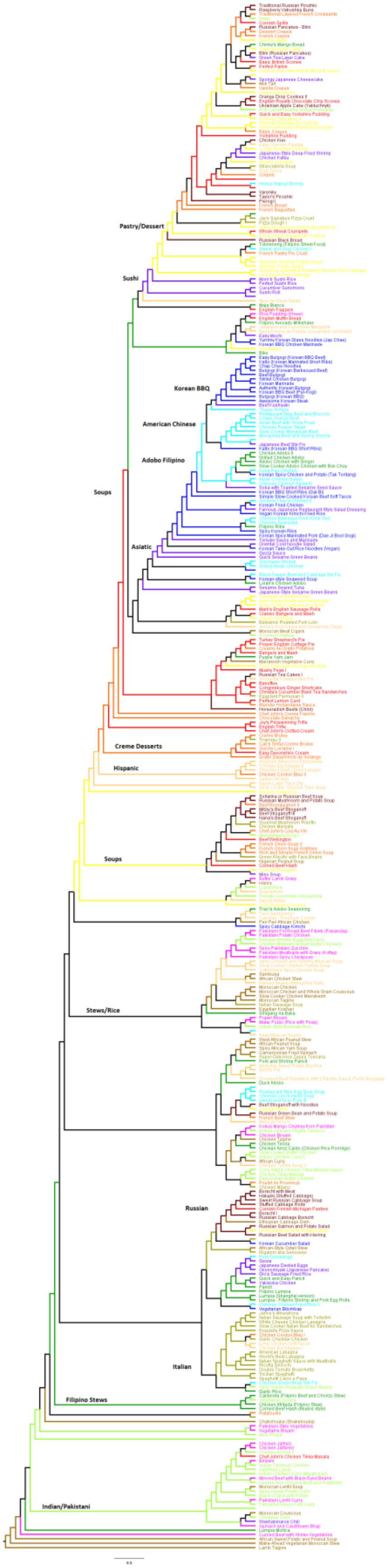
Results

Parsimony Methods

The author was unable to create a sensible consensus using parsimony methods. Inspection of a single tree generated from parsimony methods shows weak clustering based on country of origin, with repeated motifs. The tree is rooted to the recipe “Lamb Tagine” from Africa.

European countries tend to cluster together with Germanic foods, French foods, and English foods in terms of the deepest most recent common ancestor (MRCA). While it would be incorrect to say Germanic foods are ancestral to British foods as both the recipes are leafs still in existence today, it does emphasize how closely these three countries share culinary traditions. South-east Asian countries tended to cluster together in terms of recipes. India and Pakistan closely clustered, and oddly Mexico and African recipes tended to cluster into these groups. Italy formed its own distinct cluster on the parsimony tree.

The repeated motifs on the tree appear to be caused by clustering by recipe type. The German-French-British motif appears in a region of the tree dominated by desserts/pastries, then again in a soup dominant part of the tree. There was also a pasta dominant, a stew dominant, and a BBQ dominant section of the tree as well. The parsimony methods likely caused this due to a different set of ingredients being needed to bake rather than to broil.


Pastry/Dessert
Sushi
Korean BBQ
American Chinese
Adobo Filipino
Soups
Asiatic
Creme Desserts
Hispanic
Soups
Stews/Rice
Russian
Italian
Filipino Stews
Indian/Pakistani
Traditional Russian Pirozhki
Raspberry Vatrushka Buns
Traditional Layered French Croissants
Naan
Cornish Splits
Russian Pancakes - Blini
Dessert Crepes
French Crepes
German Baby
Chinky's Mango Bread
German Apple Cake I
Blini (Russian Pancakes)
Green Tea Layer Cake
Basic British Scones
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German Pancake with Buttermilk Sauce
Spongy Japanese Cheesecake
Milk Tart
Vanilla Crepes
Kaiserschmarren
Orange Drop Cookies II
English Royalty Chocolate Chip Scones
Ukrainian Apple Cake (Yabluchnyk)
Roti Canai/Paratha (Indian Pancake)
Quick and Easy Yorkshire Pudding
German Pancakes II
German Spaetzle Dumplings
Semmelknoedel (Bread Dumplings)
Basic Crepes
Yorkshire Pudding
Chicken Kiev
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Crispy Roasted Chicken
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Chicken Katsu
Wiener Schnitzel
Stracciatella Soup
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Crepes
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French Baguettes
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Pizza Dough I
Authentic German Bread (Bauernbrot)
Whole Wheat Crumpets
Papa Drexler's Bavarian Pretzels
Russian Black Bread
Tokneneng (Filipino Street Food)
Sweet and Sour Chicken I
French Pastry Pie Crust
Authentic German Potato Salad
German Potato Salad
Grandma Jeanette's Amazing German Red Cabbage
Lili's Apple Red Cabbage
Mom's Sushi Rice
Perfect Sushi Rice
Cucumber Sunomono
Sushi Roll
Mexican Bean Salad
Maja Blanca
English Flapjack
Rice Pudding (Kheer)
English Muffin Bread
Filipino Avocado Milkshake
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Chinese Pepper Steak
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Mongolian Beef and Spring Onions
Japanese Beef Stir-Fry
Kalbi (Korean BBQ Short Ribs)
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Adobo Chicken with Ginger
Slow Cooker Adobo Chicken with Bok Choy
Kung Pao Chicken
Korean Spicy Chicken and Potato (Tak Toritang)
Asian Chicken Salad
Chinese Chicken Salad III
Soba with Toasted Sesame Seed Sauce
Korean BBQ Short Ribs (Gal-Bi)
Simple Slow-Cooked Korean Beef Soft Tacos
General Tsao's Chicken II
Korean Fried Chicken
Famous Japanese Restaurant-Style Salad Dressing
Vegan Korean Kimchi Fried Rice
Chinese Barbeque Pork (Char Siu)
Chinese Spareribs
Filipino Ribs
Spicy Korean Ribs
Korean Spicy Marinated Pork (Dae Ji Bool Gogi)
Teriyaki Sauce and Marinade
Oriental Cold Noodle Salad
Korean Take-Out Rice Noodles (Vegan)
Gyoza Sauce
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Szechwan Shrimp
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Lolah's Chicken Adobo
Sesame Seared Tuna
Japanese-Style Sesame Green Beans
Sausage and Sauerkraut
Beer Glazed Brats and Sauerkraut
Slow Cooker Kielbasa and Beer
Mark's English Sausage Rolls
Classic Bangers and Mash
Jaeger Schnitzel
Balsamic Roasted Pork Loin
Annie's Fruit Salsa and Cinnamon Chips
Moroccan Meat Cigars
Coconut Chutney
Turkey Shepherd's Pie
Proper English Cottage Pie
Creamy Au Gratin Potatoes
Bangers and Mash
Purple Yam Jam
Marrakesh Vegetable Curry
Fried Cabbage and Egg Noodles
Mushy Peas I
Russian Tea Cakes I
Sopapilla Cheesecake Pie
Banoffee
Congresbury Ginger Shortcake
Christa's Cucumber Basil Tea Sandwiches
Eggplant Parmesan II
Perfect Lemon Curd
Blender Hollandaise Sauce
Horseradish Beets (Chrin)
Chef John's Creme Fraiche
Chocolate Ganache
Joy's Prizewinning Trifle
English Trifle
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Salsa Chicken
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Beef Stroganoff III
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Mulligatawny Soup I
Beef Wellington
French Onion Soup V
French Onion Soup Gratinee
Rich and Simple French Onion Soup
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Pakistani Pot Roast Beef Fillets (Pasanday)
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Chicken Makhani (Indian Butter Chicken)
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Spicy Chicken and Hominy Mexican Soup
Slow-Cooker Chicken Tortilla Soup
Catherine's Spicy Chicken Soup
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African Chicken Stew
Refried Beans Without the Refry
Moroccan Chicken
Moroccan Chicken and Whole Grain Couscous
Slow Cooker Chicken Marrakesh
Moroccan Tagine
Italian Sausage Soup
Egyptian Koshari
Sinigang na Baka
Prawn Biryani
Matar Pulao (Rice with Peas)
Indian Style Basmati Rice
Easy Mexican Sopes
West African Peanut Stew
African Peanut Soup
Spicy African Yam Soup
Cameroonian Fried Spinach
Super-Delicious Zuppa Toscana
Pork and Shrimp Pancit
Addictive Sweet Potato Burritos
Burrito Pie
Drowned Beef Sandwich with Chipotle Sauce (Torta Ahogada)
Duck Adobo
Restaurant Style Egg Drop Soup
Chinese Lion's Head Soup
Sweet and Sour Pork III
Beef Stroganoff with Noodles
Jagerschnitzel
Russian Green Bean and Potato Soup
French Beef Stew
Mexican Rice II
Kokus Mango Chutney from Pakistan
Grilled Chicken Thighs Tandoori
Chicken Biryani
Chicken Tagine
Chicken Tinola
Chicken Arroz Caldo (Chicken Rice Porridge)
Slow Cooker Butter Chicken
Indian Chicken Curry II
African Curry
Chicken Tortilla Soup V
Curry Stand Chicken Tikka Masala Sauce
Chicken Tikka Masala
Easy Indian Butter Chicken
Poulet de Provencal
Chicken Milano
Borscht with Meat
Halupki (Stuffed Cabbage)
Sweet Russian Cabbage Soup
Stuffed Cabbage Rolls
Cornish Finnish Michigan Pasties
Borscht I
Russian Cabbage Borscht
Ethiopian Cabbage Dish
Russian Salmon and Potato Salad
Octoberfest German Potato Salad
Russian Beet Salad with Herring
Korean Cucumber Salad
African-Style Oxtail Stew
Rigatoni alla Genovese
Pork Dumplings
Gyoza
Japanese Deviled Eggs
Okonomiyaki (Japanese Pancake)
Olo's Sausage Fried Rice
Quick and Easy Pancit
Yakisoba Chicken
Pancit
Filipino Lumpia
Lumpia (Shanghai version)
Lumpia - Filipino Shrimp and Pork Egg Rolls
Chinese Chicken Fried Rice II
Vegetarian Bibimbap
Jamie's Minestrone
Italian Sausage Soup with Tortellini
White Cheese Chicken Lasagna
Slow Cooker Italian Beef for Sandwiches
Exquisite Pizza Sauce
Chicken Cordon Bleu I
Garlic Cheddar Chicken
Lime Chicken Soft Tacos
Chicken Enchiladas I
American Lasagna
World's Best Lasagna
Italian Spaghetti Sauce with Meatballs
Ricotta Gnocchi
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Sicilian Spaghetti
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Caldereta (Filipino Beef and Chorizo Stew)
Vegetarian Korma
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Pakistani Style Vegetables
Vegetable Biryani
Aloo Bhujia
Chicken Jalfrezi
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Chef John's Chicken Tikka Masala
Biryani
Indian Tandoori Chicken
Kashmiri Lamb
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Lumpia Mollica
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African Sweet Potato and Peanut Soup
Make-Ahead Vegetarian Moroccan Stew
Lamb Tagine

Legend

England

France

Germany

Russia

Italy

China

Korea

Japan

Philippines

India

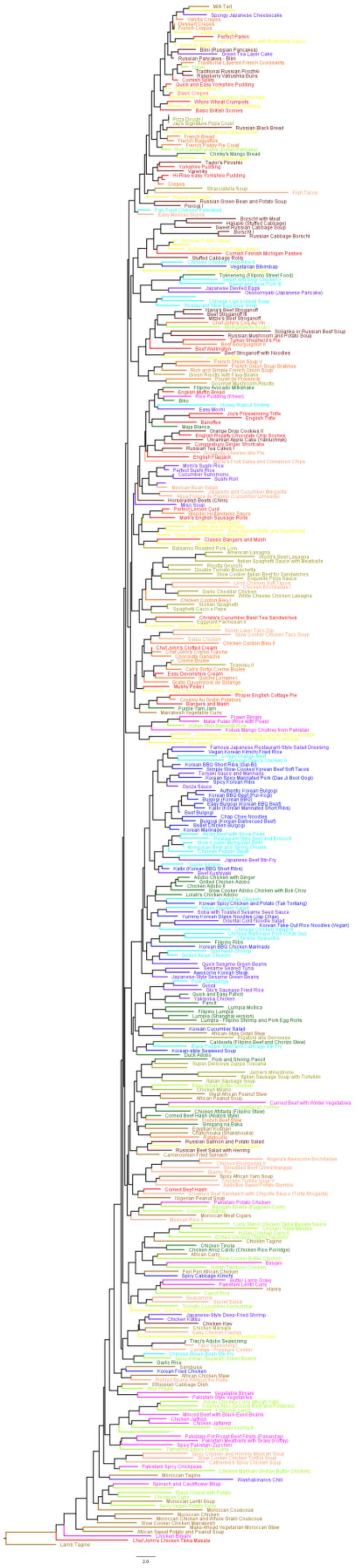
Pakistan

Mexico

Africa

Distance Methods

The tree is rooted to the recipe “Lamb Tagine” from Africa. The neighbor joining method showed a clear distinction between Asiatic recipes and all other (European, African, Hispanic). There was better clustering on a per country level, with more contiguous grouping of clades. The “honey walnut shrimp” Chinese recipe, Chinese egg drop soup, as well as a few Filipino recipes and Indian buttered chicken clustered into the European side of the tree unexpectedly, suggesting either a type of convergence in the culinary tradition, or an inauthenticity in the recipe. The methods used for building the neighbor joining tree did not take into account the types of ingredients used directly perhaps allowing better broad clustering than parsimony methods.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Butter Lamb Gravy
Pakistani Lentil Curry
Harira
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Lamb Tagine
2.0

Legend

England

France

Germany

Russia

Italy

China

Korea

Japan

Philippines

India

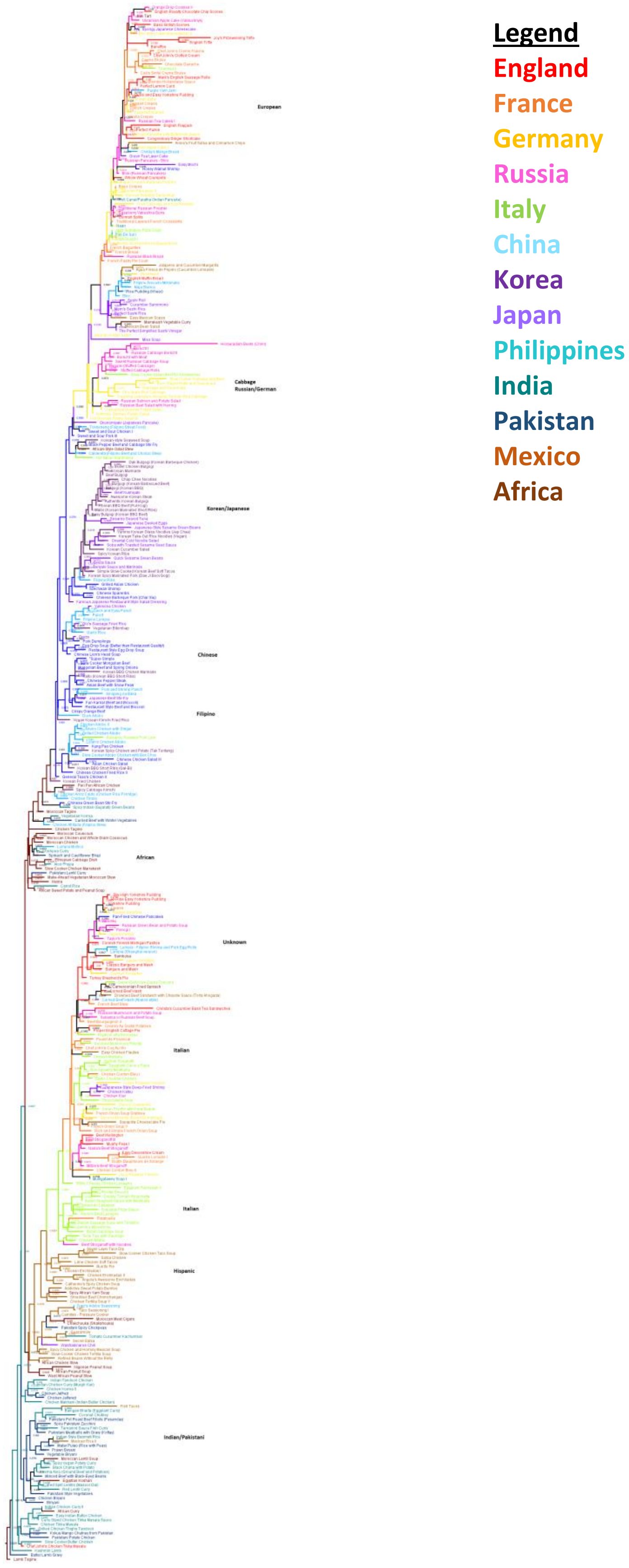
Pakistan

Mexico

Africa

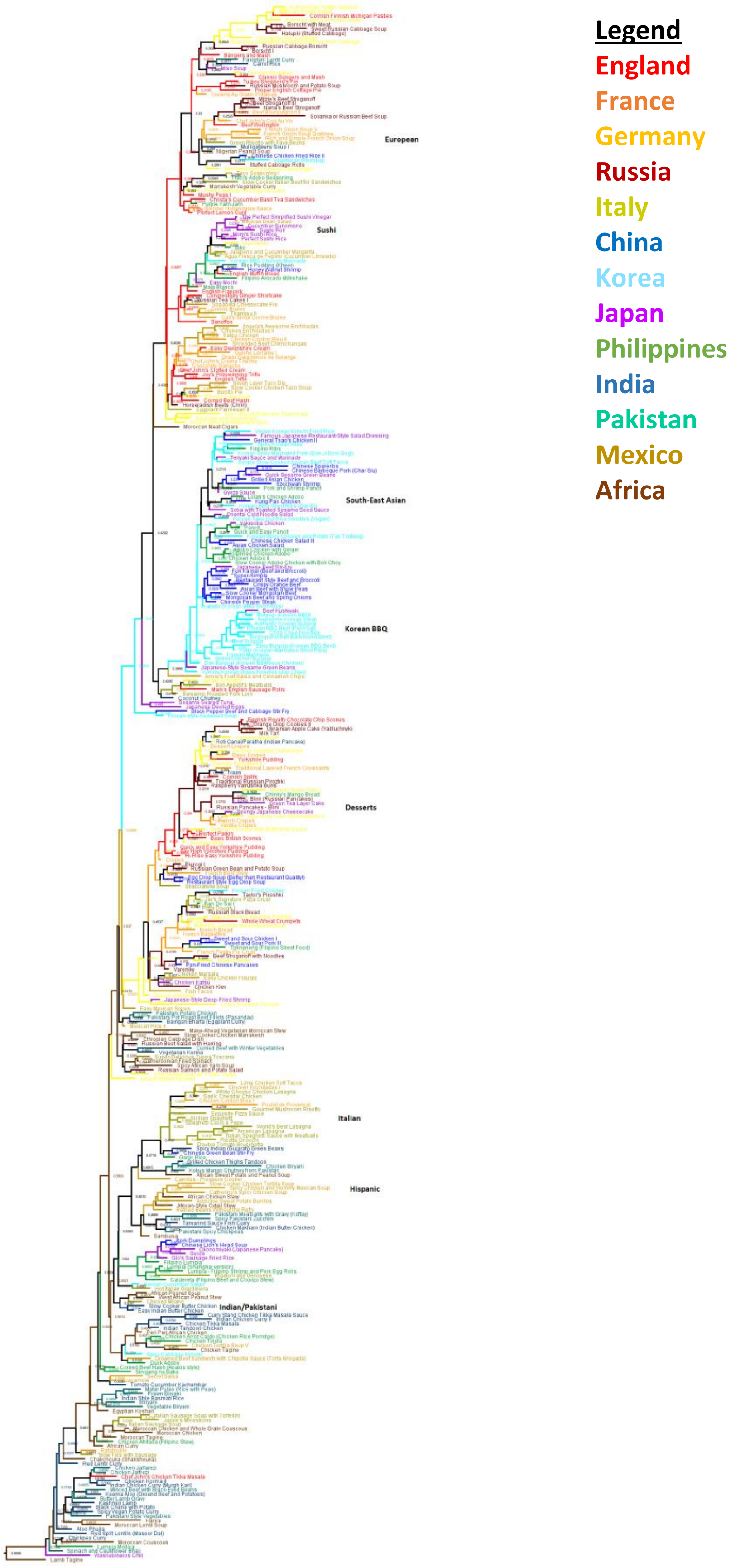
Maximum likelihood methods

The tree is rooted to the recipe “Lamb Tagine” from Africa. Maximum likelihood methods show good ability to separate out recipes by culinary culture, creating multiple contiguous groupings. It further is able to show shared culinary tradition, such as between Pakistan and Indian, as well as between Korea and Japan, and to a lesser extent China. Despite the improvement of clustering form prior methods, the bootstrap values are low, suggesting a less robust support for the results shown.


European
Cabbage Russian/German
Korean/Japanese
Chinese
Filipino
African
Unknown
Italian
Italian
Hispanic
Indian/Pakistani
Legend
England
France
Germany
Russia
Italy
China
Korea
Japan
Philippines
India
Pakistan
Mexico
Africa

Bayesian Methods

The tree is rooted to the recipe “Lamb Tagine” from Africa. The Bayesian analysis failed to converge and create a reasonable consensus tree, so a tree was selected from the higher scoring regions of tree space. The result is comparable with the maximum likelihood tree, albeit a little less straight forward. There is obvious clustering between south-east Asian cultures as well as between India and Pakistan. Many of the recipes labelled as “Mexican” are grouped inside the European parts of the tree. There are still low support values for the branches, emphasizing the uncertainty of the placement. Future runs should consider longer searches through tree space with parameters set that would force swapping between chains, to avoid becoming stuck in any area of tree space.


European
Sushi
South-East Asian
Korean BBQ
Desserts
Italian
Hispanic
Indian/Pakistani
Legend
England
France
Germany
Russia
Italy
China
Korea
Japan
Philippines
India
Pakistan
Mexico
Africa

Discussion

Before any evaluation of the methods or their results can be had, it is imperative to discuss the caveats and limitations of this experimental exercise of phylogenetic methods. First and foremost, AllRecipes.com is a low-quality data source for recipes. This is exemplified by some recipes calling for premade ingredients, such as taco mix or canned soups, which are much more readily available in the United States rather than globally. The majority of recipes present on AllRecipes.com are interpretations of authentic recipes, most likely from an American perspective. Because the recipes are not being made in traditional ways from traditional ingredients, the signal is obscured. Better reconstruction and clustering of recipe groups may have been found if authentic recipe books or other likewise stronger data source had been used.

Additionally, upon closer inspection of the data, repeats in recipes can be seen. While the recipes selected were listed as the best of group on AllRecipes.com, there are repeats of recipes such as bulgogi. While not inherently bad for the phylogenetic process, it gives an artificial sense of success in clustering using the phylogenetic method.

For this study, low information content terms were used. Rather than stick with higher content terms such as “yellow onion”, “green onion”, etc., the author opted to truncate the term to simply onion, potentially losing information that could have helped better discriminate between different classifications better. To sum up the prior three points simply, attempting to put “garbage in” into phylogenetic methods will lead to getting “garbage out.” Careful data selection and curation is essential to getting meaningful results using phylogenetic methods, whether it is from morphological data from recipes, or species data from animals.

From all the methods, maximum-likelihood produced the most contiguous tree that was consistent with prior knowledge on how food practices spread based on proximity. Parsimony methods over-fragmented the population of recipes with respect to ingredient, forming clades more consistent with the type of food being served. Distance methods could sort between Asiatic and European dishes, but were not able to cluster very well based on country. This is potentially because of a loss in data on what the characters were. Maximum-likelihood results had the best clustering per known countries. Bayesian methods did not converge, and should be repeated in the future, but the higher-ranking trees are near comparable to the maximum likelihood trees.

From the maximum likelihood tree, it is difficult to discern a distinct origin between Pakistani dishes and Indian dishes, which is consistent with the known culture of these two countries. They had split in 1947 after World War II, a decision made by the British. The South-East Asian countries of China, Japan, Korea, and the Philippines clustered together in terms of recipes, as would be expected with prior knowledge on trade and conflict between these countries. Despite the similarities shown on the tree, each of these cultures has a unique culinary tradition, which may have been missed during clustering due to the use of low quality recipes or low information content terms. Interestingly, some Hispanic recipes are rooted inside European recipes, while another set are located near Indian/Pakistani dishes. Further investigation could be made to see if this is due to a heavy European influence on the culinary tradition due to colonization, or if this is an artifact of the low quality dataset. English, French, German, and Russian recipes are all tightly mixed, suggesting perhaps heavy mixing of culinary innovation. This would be consistent with knowledge of past trade and conflict. Perhaps interestingly, it should be noted that two Japanese dishes are nested inside the European dessert section of the tree, “spongy Japanese cheesecake” and “green tea layered cake”. Prior knowledge will show the innovation for the creation of these types of cake are of European origin (Italian Chef Giovan Battista Cabona working in Giovan Battista Cabonahe Spanish court), with the Japanese adopting the culinary innovation and modifying it to suite their palate in the recent past through a horizontal transmission event of culture. Other similar events can be found in the maximum likelihood tree, but a subject matter expert would be required to appropriately interpret the result.

With modern modes of transportation and the innovation of the internet, cultures are able to horizontally integrate at a much faster rate than ever before. It is increasing becoming difficult to find cultures in isolation with unique hallmarks. Despite globalization, many countries still maintain culinary traditions which were developed based on regional availability as well as locally defined palettes. Globalization is spreading ‘invasive species’ of food around the world, some which sustain very well.

References

1. Gray, R. D., Drummond, A. J., & Greenhill, S. J. (2009). Language phylogenies reveal expansion pulses and pauses in Pacific settlement. science, 323(5913), 479-483.
2. Bouckaert, R., Lemey, P., Dunn, M., Greenhill, S. J., Alekseyenko, A. V., Drummond, A. J., ... & Atkinson, Q. D. (2012). Mapping the origins and expansion of the Indo-European language family. Science, 337(6097), 957-960.
3. Le Bomin, S., Lecointre, G., & Heyer, E. (2016). The evolution of musical diversity: the key role of vertical transmission. PloS one, 11(3), e0151570
4. Rambaut, A. (2012). FigTree v1. 4. *Molecular evolution, phylogenetics and epidemiology. Edinburgh, UK: University of Edinburgh, Institute of Evolutionary Biology*.
5. Giribet, G. (2005). TNT: tree analysis using new technology.
6. Paradis, E., Claude, J., & Strimmer, K. (2004). APE: analyses of phylogenetics and evolution in R language. Bioinformatics, 20(2), 289-290.
7. Stamatakis, A. (2014). RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics*, *30*(9), 1312-1313.
8. Ronquist, F., & Huelsenbeck, J. P. (2003). MrBayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics*, *19*(12), 1572-1574.