World Food Atlas for Food Navigation

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ABSTRACT

Food plays a central role in agriculture, public wellness, public health, culinary art, and culture. Food-related data is available in varying formats and with different access levels ranging from private datasets to publicly downloadable data. Every food-related query, in principle, is a food recommendation problem. We analyze the components of a food recommendation and its requirements. We demonstrate the effectiveness of having access to worldwide food data from divergent aspects for answering food- and health-related queries that would otherwise be expensive and require specialized domain expertise. We present the World Food Atlas (WFA): An open-source platform for different stakeholders in the food ecosystem to share their data on a global data hub with a singular point of access. The world food atlas contains the availability and inter-connectivity of food and its effects in various forms. We gather real-world questions by partnering with nutritionists, dietitians, and doctors. We categorize the practical food queries to construct requirement tables and develop a novel schema to satisfy the requirement table to model the world food atlas. Finally, we demonstrate how food and lifestyle navigation systems can use the world food atlas to enable personalized and context-driven solutions to person-entity-context queries.

CCS CONCEPTS

• Information systems → Search engine architectures and scalability; **Information integration**; **Collaborative and social computing systems and tools**; **• Applied computing → Health care information systems**; **Health informatics**; **• Computing methodologies → Knowledge representation and reasoning**; **Search methodologies**.

KEYWORDS

food recommendation, food knowledge graph, personal food model, health navigation, recipe dataset, food schema, health effect queries

1 INTRODUCTION

Humans have been scrutinizing food from diverse perspectives. Societal evolution and the associated technological revolution have given rise to a data-driven approach toward food. Data related to food is diverse, rich, and multidimensional and interacts with multiple components [20]. Food has a direct impact on people's health [17]. Positive changes to food habits and changes in dietary practices lead to better health outcomes. Receiving the correct food recommendation at the appropriate time has the potential to reduce symptoms of chronic diseases, enable people to make healthier lifestyle choices, and increase overall happiness. For a food navigation system to be effective and not result in a hedonic treadmill, the recommendations should be based on a person's food model rather than being derived from a population-level hypothesis. We discuss the components and requirements of contextual food navigation systems with a focus on health and personal preference to formulate the food recommendation.

In most cases, the search query is about the food to be consumed [1][15]. We currently lack an effective food navigator that provides accurate food recommendations due to a disconnect between the data sources and the limited consideration of an individual's food profile, demography, and location. We build the World Food Atlas to unify food data across the globe in a standardized manner with a special emphasis on location-based data to answer complex food-related queries at the right time. Food has a wide-ranging impact across multiple sectors in the fields of healthcare, agriculture, public policy, and the environment.

Recent work [27] provides an overview about a world food atlas to connect different aspects of food. However, there is no clear architecture presented to achieve this goal. Furthermore, while [11] mentions the need to build interconnected food networks, a working knowledge graph is yet off the table. A knowledge graph contains rich information about its entities and acts as a tool that can be leveraged to build future food navigation systems. The World Food Atlas is a platform that enables food navigation by extracting data from multiple sources needed from different locations.

In this paper, we make the following contributions. We discuss what food navigation systems are and how every food-related problem is a recommendation problem. Later, we discuss various queries from stakeholders in the food ecosystem. We then present a world food atlas architecture to answer food queries for food recommendation and navigation as shown in Figure 1. Finally, we showcase an experiment where we interview physicians, nutritionists, and doctors from Stanford University to find out what kind of queries they would ask a WFA and we design a WFA schema to demonstrate a full platform to solve real-world food-related problems.

2 RELATED WORK

The idea of a world food atlas is first proposed in [27] captures information about food across the world by integrating food logs about athletes and recipe logs [2]. The paper outlines a food knowledge graph (FKG) capturing information about restaurants, ingredients,

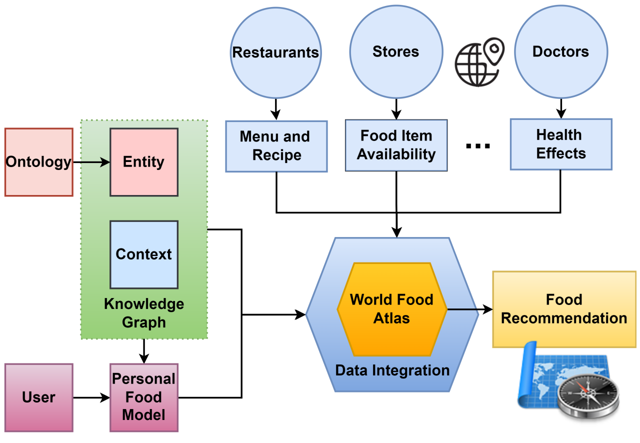

Figure 1: World Food Atlas for Food Recommendation

recipes, nutritional content, and ontological [7] information about food products. However, apart from providing a preliminary design, detailed descriptions of different systems components and relationships between them are missing.

A collection of research articles, data sources, and identification of common themes of food knowledge graphs and their applications in the industry is presented in [21]. Food knowledge graphs have different meanings depending on the context and application. However, synthesis and critical review of different sources are missing. The value of constructing food knowledge graphs for personalized food recommendation systems is discussed in [6]. However, the recommendation system works on a limited dataset and provides limited details about the design process involved in food knowledge graphs. Though the semantics and design of the food knowledge graphs for food recommendation are presented in [11], it lacks a crowdsourcing mechanism for expanding data and components for the food knowledge graph.

The food environment atlas [5] is a platform to capture data-driven information about food choices and diet quality to identify patterns that can be used to formulate policy interventions for the community's health. The atlas provides information about food insecurity, food assistance programs, physical activity, and the socio-economic status of the population across the United States. The atlas is among the few that have detailed information about the data collection process, associated documentation, and more importantly downloadable datasets for further use. Though the maps can be customized, the user interface is not intuitive. The tool is academic-oriented and is used by researchers for policy-making, data analysis, and predictions. There is a need to make the environment atlas more user-friendly by improving the user interface, and design.

The food research access atlas [25] is another atlas developed by the USDA to capture information about access to supermarkets, especially by low-income populations. It provides downloadable census tract data that can be used for creating an accessible food network and for population-level planning. Like the food environment atlas, though the food access research atlas allows customize-able visualization and download of food access data for different populations and sub-populations, there exists scope for improvement to the user interface to allow use beyond the research community.

Vermont's Food System Atlas [30] is an interactive online tool that provides information about resources across the food supply chain ranging from production to marketing. With options to download and export data, the atlas serves as a valuable tool to understand the food landscape. Wisconsin's Farm Fresh Atlas [10] is another online searchable atlas that provides information about farmer's markets, restaurants, grocery stores, and businesses within the region. The Maine Food Atlas [8] is a comprehensive atlas that encompasses people, businesses, and organizations with Maine's food system. Researchers, scientists, and businesses can request raw data to improve the food security landscape in the region. Another popular food atlas is the taste atlas [4]. The atlas consists of an online world map that details common food items, their recipes, and their historical and cultural background. However, there is a need to improve the robustness of the tool by increasing the number of dishes from various cuisines and improving the search functionality of nearby restaurants serving dishes captured on the map.

The food waste atlas [31] is a comprehensive tool that allows users to query food loss and food waste data across multiple stages in the food supply chain and across different sources. The database is however updated only till 2013 and there is a need to integrate the latest data from the United Nations. Further, a web interface for customized visualization of trends across years, for different countries and filtering based on data sources will be valuable in understanding historical trends. We face the double burden of food waste and hunger across the world. The Hunger Map [24] is a live interactive tool developed by the World Food Programme to monitor, predict and display information about food insecurity across populations throughout the world. A social food atlas [3] based in Italy to increase awareness about socially relevant food projects thereby creating a community geared towards sustainable food practices. Vienna's food atlas [29] is an effort to capture the historical and cultural significance of common foods in the region increasing awareness about food and spurring conversations about creating sustainable ecosystems.

The current food atlases display data from a limited number of sources and do not provide contextualized information. They operate in silos and cater only to specific population groups such as researchers and businesses. However, individual contributors and the larger community of data generators and contributors are neglected. There is no standardized process to submit data which discourages users from submitting data. We overcome these pitfalls by designing a world food atlas that acts as a food navigation system for stakeholders across the food ecosystem. Our unique WFA platform architecture collects and integrates data from multiple sources which serves as the precursor to food recommendation systems. To enable stakeholders to contribute data positively, we develop a novel WFA schema that gives structure to the data input and enables incorporating data from multiple avenues.

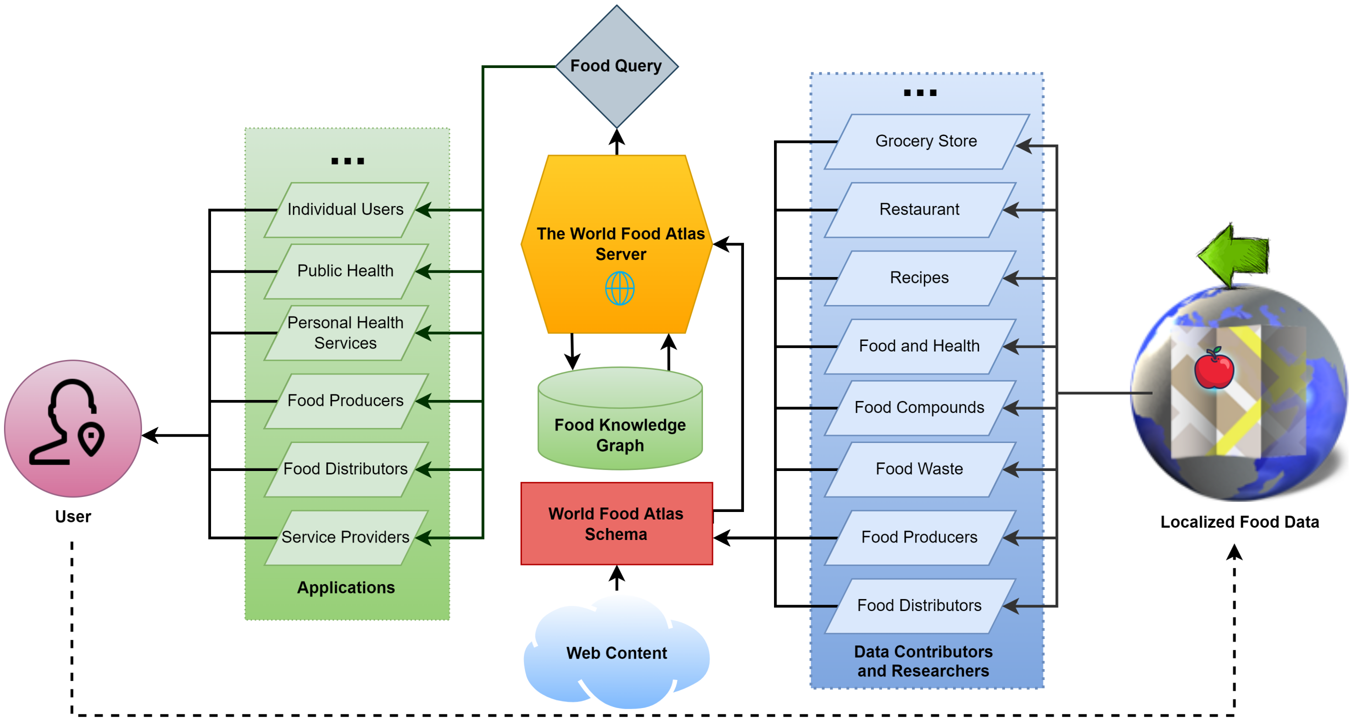

Figure 2: World Food Atlas Architecture: The localized food data is posted onto WFA via the schema and is available for various food-related applications.

3 FOOD NAVIGATION

An individual's food and health goals are multiplexes [12], Guiding an individual to their desired state through dietary recommendations that are practical and desirable has been a challenging task for nutritionists for decades. The problem of navigating to geographical locations has been solved through digital atlases and GPS systems. Directions to navigate to the desired destination is possible via a defined path with specific instructions at each step. However, food navigation is yet to be solved due to the complex nature of queries individuals have. But what direction should we take in our lifestyle towards a pleasurable, healthy, and yet convenient diet? Multimedia research has evolved greatly in providing smart, personalized, and contextual recommendations in different domains such as geographical directions but has not yet evolved to provide satisfactory food recommendations. The world food atlas answers complex person-entity-context queries asked by food recommendation systems to provide accurate lifestyle navigation tools at the right place and the right time. Food navigation, health navigation, and lifestyle navigation systems are closely related since nutrition, health and lifestyle are closely correlated. A healthy lifestyle combined with physical activities, and a healthy diet can help you maintain a healthy weight, reduce the risk of chronic deceases, and improve overall health. However, this direction is mainly focused on health ignoring lifestyle, context and pleasure leading to recommendations that are impractical and hard to follow.

As discussed earlier, the world food atlas connects multiple layers of food data on a map. The information from each source is important for a user's contextual query. Creating a food knowledge graph for building an atlas, while useful, is not sufficient [11]. While the knowledge graph has rich information about its entities, there are limitations for connectivity between external food data sources and lacks any online contributions. We, therefore, build the World Food Atlas to integrate multiple data sources and data streams and enable worldwide contributions.

The world food atlas (WFA) is a singular data hub for food data from a wide range of sources. A central component of the WFA is to process and store multi-layered location-based data. However, the centralized point of access in the WFA presents a decentralized association to promote highly collaborative contributions on a global level, all from a single point of entry. The WFA is complementary to the upcoming FKG networks discussed in the related work section. To enable integrated crowd-sourcing, we provide a schema which is a standard format for posting entity data on WFA. While some entities such as eateries and stores are directly on the map some such as the health effects and molecules data will go through processes that map them to statistical regional data. Such a system would be great for unforeseen epidemics such as Covid-19 sine we can view the spread of the virus and its mutation on the map and compare the data with the eating lifestyles of different cultures and regions around the world to infer critical information about the situation. We solve complex person-entity-context queries for food recommendations through the world food atlas as elaborated in the subsequent sections. and provide asked by food recommendation engines as elaborated in the subsequent sections.

4 QUERYING THE WORLD FOOD ATLAS

Food data is multidisciplinary, multidimensional, and multimodal and plays a key role in every aspect of society. It is generated and used by a variety of stakeholders in the healthcare, agriculture, cosmetics, and entertainment industry. Each stakeholder may have questions related to personalized food recommendations, health effects of food, and lifestyle management. Food navigation platforms service queries while collecting food- and health-related data to build a user's personal food model (PFM) [26]. When combined with the location, time, and relationship with other entities, the queries serve to answer the food recommendation problem.

Using the world food atlas, we process person-entity-context queries which enable food recommendation platforms to move towards contextual and personalized data-driven approaches to recommend the right kind of food at the right time. We list certain queries that are related to food and that have an impact on health which can be answered using the World Food Atlas. We show the relationship between food, health, context, and user with the world food atlas while answering health-related queries in Figure 3. We detail specific query examples by potential users and outline general query classes that could be generated by members of the community.

Every query has a question-answer pair where the input is a question and the output is the answer from the WFA. A common query type includes searching for ingredients or food items useful to attain health goals. A few examples of health class questions include - What food items help relieve stress? Which snack can contribute towards improving my sleep quality and costs less than 10 USD? A food item has a target health effect within a given context and can be represented as follows.

$$(Effect_t, Context_v) \longrightarrow Food$$

The $Effect_t$ represents the target effect and the $Context_v$ represents the context vector.

On the contrary, users may ask questions about the impact certain kinds of food can have on their health within a particular context. For example, what impact will drinking three cups of coffee have on me as a 50-year-old African-American woman? The relationship is represented as follows.

$$(Food, Context_v) \longrightarrow Effect_t$$

Questions of this nature vary based on an individual's political, religious, and geographical backgrounds and may have answers that contradict medical findings. Additionally, a person's food model [26] leads to different health effects for the same food consumption patterns and quantity.

As shown in Figure 3, using the WFA, we obtain responses to these queries using real-world data. We examine current medical findings to find research-backed food recommendations by the medical community for the desired health effect for a specific context. Through the WFA, we also examine population-level life log data of people across the world to recommend food items that help achieve health goals in a specific context. Conversely, if users search for the effect of eating a certain type of food on their health, the WFA scrutinizes lifelogs from multiple stakeholders and medical findings across the research community to find potential health effects of food items.

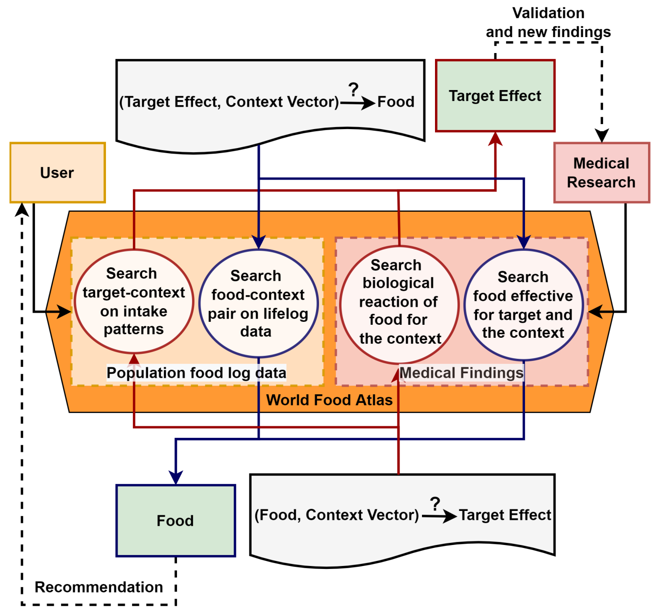

Figure 3: Health-related queries encompass questions that affect the user's biology. We generalize complex questions by categorizing them into specific query classes. We ask about the impact of certain types of food on the desired health state and measure the health effects of consuming certain kinds of food, both within a context. We aim to answer these questions through the World Food Atlas through an event mining approach and by leveraging medical research findings.

In some instances such as dietary restrictions for users, contextual information bears prominence for food and health-related queries. Existing work [18] generates recipes based on user's preference history using limited data about food. Such platforms consist of contextual preferential queries on food. A few examples are - What dishes can I make to prevent soy allergies? What recipes can I use to make lamb curry that is low in cholesterol and saturated fat? And that can take into consideration all the limitations that a person might have for cooking at home or for ordering the food.

$$(Requirement_v) \longrightarrow Recipes$$

The $Requirement_v$ represents the requirements vector.

What restaurants can I go near me which has vegan food?

$$(Requirement_v, Context_v) \longrightarrow Restaurant$$

Data generated by users through lifestyle navigation apps are used to build personal models [26] around food, emotion, sleep, stress, and physical activity. Food recommendation systems have aimed to model the preference of the users [23] to answer some questions such as: What do I eat when I am stressed? In what context do I prefer drinking tea in the evening? When do I eat spicy food? When do I crave sweets? What foods cause sleep discomfort at night? How does my current diet affect acid reflux? These queries can be represented using the following class.

$$(PersonalLog, Context_v) \longrightarrow Food$$

The *PersonalLog* represents the personal lifelog and food log data of the person.

Today with various wearable sensors, logging real-time biological signals is possible for a wide range of users across the world [9]. Compact sensors play a critical role in the acquisition of physical, chemical, or biological data [22]. Food storage spaces can be monitored using sensors like temperature or humidity sensors [16] and nutrition can be assessed accurately using nutrition detection sensors [13]. The WFA aggregates a large connection of data from various contributors around the globe to process such queries as will be discussed in the following sections. We, therefore, design a World Food Atlas that takes a holistic data-driven approach for answering all food-related queries.

5 WORLD FOOD ATLAS ARCHITECTURE

Stakeholders across the food supply chain such as individual users, food producers, food distributors, personal health service providers, and public health authorities are contributors and consumers of food-related data. The sources of data, their format, size, frequency, collection methodology, and applications vary[20]. The geographical context and the temporal features of data play a crucial role in the way data is collected, processed, and analyzed for use in food recommendation applications[26]. However, there is a lack of a unified platform for congregating all food-related information to provide lifestyle navigation. To this end, we construct the World Food Atlas which provides an overarching framework for data collection, data representation, and food-related information retrieval.

The detailed architecture of the World Food Atlas platform is shown in Figure 2. There are multiple contributors to food-related data as shown by the blocks in the blue column. Congregating data will help explore similarities and differences between content. Most data is generated and made available by grocery stores, restaurants, food manufacturers, distributors, individual users, researchers, government agencies, research institutions, and independent agencies at the state, national, and international levels. Data from these sources is multidimensional and in varying formats. Web content also serves as an input to the world food atlas platform. Methods such as [14] use models to reconstruct the recipe information from available text such as title or ingredients.

The most challenging part is connecting the data from multiple sources and across multiple platforms in a systematic manner. We create a world food atlas schema that allows consolidating data into a unified framework. The schema forms the backbone of the world food atlas. We use the schema to standardize data sources and bring them into the world food atlas. The schema fits well into a database and can be stored on a server. When a user poses a query based on their food needs, information can be extracted from the server based on the integrated mega atlas that maps relationships between multiple sources. The data is then presented in a downloadable format. The encrypted data can be sent to individual contributors for updating their database and can be used for future use. For example, the data can be fed into a machine learning model for training and can be used for food recommendations. On the other hand, the output data from the food queries can be released publicly with appropriate citations for use by individuals, public health providers, personal health service providers, food manufacturers, food distributors, etc. This data can be integrated with food logging platforms [28], life logging applications, and population-level data by the United States Department of Agriculture, United Nations Food and Agricultural Organization, and the World Food Program.

The different stakeholders that can benefit from the world food atlas are highlighted in the green column through responses to application-specific queries. For instance, service providers can improve their food quality, food distributors can benefit from better logistics management, and food producers can leverage the WFA for designing better products. Individual users can directly use the open-source platform and public health organizations can leverage localized data output based on inputs from multiple sources. All these applications benefit from the automation capabilities offered by the world food atlas both at an individual level and at the population level. In turn, they contribute to the world food atlas through food logging applications, life logging applications, and population-level studies. There exists a feedback loop that allows sending data back to contributors.

We are among the first ones to create a simple and standardized data collection schema and architecture platform to collect food-related data thereby creating incentives for stakeholders to contribute data. We ensure that each contributor gets credit for their data by creating an identity profile for each data source which increases awareness about the data source and allows users to cite resources appropriately when used. In this way, our world food atlas architecture allows dynamic data creation, storage, and retrieval which is advanced compared to the existing atlases.

6 THE SCHEMA EXPERIMENT

The World Food Atlas is designed to become a global data hub with a location-based and time-based focus on food. Large-scale data generated by multiple stakeholders should be seamlessly imported into the platform. Doing so requires formulating multiple data classes, detailing relationships between classes, and a comprehensive data collection schema. We design a novel world food atlas schema that allows users to contribute data to the platform without having detailed knowledge of the underlying food knowledge graph. The users share data under the corresponding schema since we handle data integration internally. The World Food Atlas entity classes, their relations, and schema form the backbone of the world food atlas architecture.

The schema provides structure and consistency to the incoming data of a certain class. We show the design process and framework of the world food atlas schema in Figure 4. The different food data stakeholders include physicians, nutritionists, doctors, chefs, and individual users through data from lifestyle navigation applications such as Apple Health Kit, Google Fitbit, etc, represented by the blue rectangular column. The hexagon indicates the mechanism through which data from multiple sources is aggregated and fed into the World Food Atlas.

The stakeholders can either directly contribute to the atlas through the WFA schema or via content generated by them on the web. For example, if a restaurant wants to upload its data into the atlas, it can

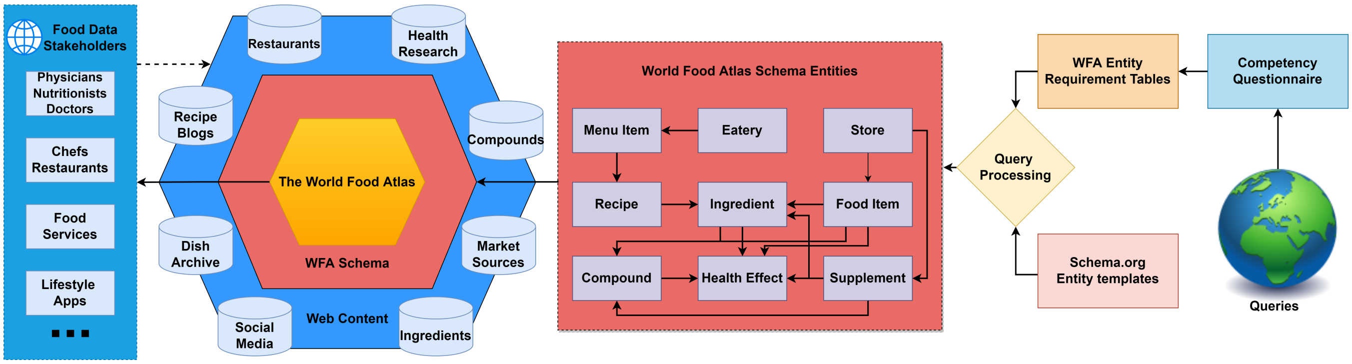

Figure 4: World Food Atlas schema Design for processing real-world queries

use the 'Eatery' schema template. Similarly, food bloggers can use the 'Recipe' schema and 'Ingredient' schema templates to upload data about their favorite recipes. Research groups [19] have put valuable effort to gather a dataset of different recipes with many images associated to each recipe and has demonstrated the great potential of such data. An effort like this requires a substantial amount of resources. While very valuable, it lacks an automated method to expand the dataset, whereas, WFA schema is a hub for large-scale recipe datasets and is constantly growing. There is a two-way street between stakeholders/contributors of food data such as doctors, chefs, food services, lifestyle navigation apps, and the world food atlas. They provide data to the atlas through the schema and they receive data based on their queries.

We draw up a list of competency questions that could potentially arise in the minds of the stakeholders. We go one step further and partner with expert nutritionists, dietitians, and doctors from Stanford University in expanding the list by seeking their opinion about questions they ask their patients while examining them. The detailed questionnaire is presented in Appendix A. The questions were mainly related to taste, cost, and health impact of food. We combine our knowledge and their inputs to create a comprehensive requirements table for queries to the world food atlas. We noticed that many requirements for different components such as recipes, menu items, and dietary supplements were satisfied by entity templates in https://schema.org. Though https://schema.org was originally used by internet giants such as Google for optimizing search on web data and for data indexing on web searches, their goal is to create a standard data representation language. We, therefore, combine our world food atlas entity requirement table taking inputs from dietitians, nutritionists, and computer scientists with entity templates from https://schema.org.

We also take into consideration aspects not covered in the competency questionnaire and schema.org to make the entity template list as comprehensive as possible. We account for events happening around the globe along with dynamic real-time information updated by different stakeholders while populating the schema entity tables. For example, aspects such as the 'non-contact delivery' option for restaurants and grocery stores due to COVID-19 and 'popular times' an eatery or store is open based on real-time occupation level given by service providers.

The components within the schema are interconnected and have dependencies on each other as shown in the red rectangle. The main components are eateries, stores, menu items, food items, dietary supplements, recipes, ingredients, compounds, and health effects. Eateries such as restaurants, fast food joints, and food trucks have certain items on their menu. Each item has a specific recipe and varies in preparation based on the eatery and the chef preparing the dish. Similarly, stores such as supermarkets, and retail stores have food items that are across multiple categories including but not limited to cereals, snacks, candies, etc. Stores either physical or online also sell dietary supplements. Food items, menu items, and dietary supplements are composed of ingredients, which are in turn constituted by compounds. Dishes, dietary supplements, ingredients, and compounds have health effects depending on their consumption amount, time, body physiology, and genetics.

We detail the different schema entities and their components in Table 1. The entities include 'Eatery', 'Store', 'Menu Item', 'Food Item', 'Dietary Supplement', 'Ingredient', 'Compound', 'Nutrition Information' and 'Health Effect'. Most of the components between the 'Eatery' entity and the 'Store' entity are similar and are derived from the schema.org entity tables. The components derived outside schema.org and competency questionnaires are - Curbside Pickup, Deals/Offers, Serves Alcohol, Smoking Allowed, Dine-in, Take Out, Non-Contact Delivery, Online Order, Popular Times, Question and Answers, Social Media, Events, and Videos. Components that are included in the 'Eatery' entity and excluded in the 'Store' entity are - 'Menu Item', Reservation, and Cuisine. Components that are included in the 'Store' entity and excluded in the 'Eatery' entity are - 'Dietary Supplement', Products/Food Items, Product Category, and Pharmacy.

Each eatery such as a restaurant has a 'Menu Item' and stores have a 'Food Item' and 'Dietary Supplement'. We distinguish 'Menu Item' and 'Food Item' because 'Menu Items' because chefs in restaurants may have different recipes for each item they prepare and can vary across restaurants whereas food items are standardized with respect to their preparation process and have fixed ingredients, composition, and nutrient content. Both 'Menu Items' and 'Food Items' comprise ingredients with associated nutrition information, a specific taste, allergens, and certain health effects. The 'food item' entity has a growing location, origin city, origin country, and shelf life in addition to all other components present in the menu item

Eatery	Stores	Recipe	Menu Item	Food Item	Dietary Supplement	Ingredient	Compound	Health Effect	Nutrition
Menu Item	**Dietary Supplement**	**Ingredient**	**Ingredient**	**Ingredient**	**Ingredient**	**Compound**	**Health Effect**	Health Benefits	Calories
Address	**Food Item**	**Nutrition**	**Health Effect**	**Health Effect**	**Health Effect**	**Health Effect**	BioChem Interaction	Misconceptions	Carbohydrate
Cuisine	Address	Category	**Nutrition**	**Nutrition**	**Nutrition**	**Nutrition**	BioChem Similarity	Symptoms	Cholestorol
Description	Description	Cook Time	Category	Category	Active Ingredients	Category	Chemical Role	Allergen Effect	Fat
Drive Thru	Drive Thru	Cooking Method	Description	Description	Category	Cost	Composition	Effect on blood glucose level	Fiber
Email	Email	Copyright Holder	Name	Distributor	Cost	Description	Description	Effect on cardio-metabolic health	Protein
Item Price	Item Price	Copyright Notice	Serving Size	Name	Description	Name	Genetic Expression	Effect on Pregnancy	Saturated Fat
Latitude and Longitude	Latitude and Longitude	Copyright Year	Suitable for Diet	Net Weight	Guidelines	Suitable for Diet	inChI	Effect on triglycerides	Serving Size
Logo	Logo	Cuisine	Deals/Offers	Serving Size	Legal Status	Deals/Offers	inChIKey	Fatty acid profile	Sugar
Name	Name	Date Created	Allergens	Suitable for Diet	Manufacturer	Allergens	IUPAC Name	Pre-, pro-, post- biotic content	Trans Fat
Open Hours	Open Hours	Date Modified	Cost	Taste	Maximum Intake	Glycemic Index	Molecular Formula	Side Effects	Unsaturated Fat
Payment Method	Payment Method	Description	Taste	Deals/Offers	Mechanism of Action	Insulin Index	Molecular Function		% Daily Value
Phone	Phone	Instructions		Growing Location	Medicine System	Shelf Life	Molecular Weight		Electrolytes
Photo	Photo	Name		Origin City	Name	Taste	Name		Minerals
Price Range	Price Range	Photos		Origin Country	Proprietary Name		Potential Use		Vitamins
Reservation	Review	Prep Time		Allergens	Recognizing Authority		Proprietary Name		
Review	Star Rating	Reviews		Cost	Recommended Intake		Smiles		
Star Rating	Website	Star Rating		Shelf Life	Safety Consideration		Subcellular Location		
Website	Curbside Pickup	Steps			Suitable for Diet		Taxonomic Range		
Curbside Pickup	Deals/Offers	Suitable for Diet			Target Population		Taste		
Deals/Offers	Dine-in	Total Time			Deals/Offers				
Dine-in	Events	Website			Allergens				
Events	Non-Contact Delivery	Yield			Shelf Life				
Non-Contact Delivery	Online Order	Videos			Taste				
Online Order	Pharmacy	Cost							
Popular Times	Popular Times	Tools/Utensils							
Question and Answers	Product Categories								
Serves Alcohol	Question and Answers								
Smoking Allowed	Serves Alcohol								
Social Media	Smoking Allowed								
Take Out	Social Media								
Videos	Take Out								
	Videos								

Legend
- Web Content
- schema.org
- Questionnaire

Table 1: WFA Schema Components

entity. Most of the information for the 'Dietary Supplement' entity is derived from schema.org. Though more fields were present that captured various aspects of dietary supplements, we decide to provide a representative sample that captures most of the information and is simple enough to be uploaded by non-expert stakeholders and data contributors.

'Recipes', 'Menu Items', 'Food Items', and Dietary Supplements contain 'Ingredients'. We expand the ingredient components of schema.org to include aspects such as insulin index, glycemic index, and origin information apart from standard information such as nutritional content and suitability for certain diets among others. Each 'ingredient' has multiple 'compounds' and each compound has different properties mostly derived from schema.org such as molecular weight, molecular formula, IUPAC name, and so on as described in the table. Each 'menu item', 'food item', 'dietary supplement', 'ingredient' and 'compound' consumed has a certain 'health effect'.

We understand different health effects by consulting with nutritionists, doctors, and medical experts. We also incorporate certain components of the health aspect entity table from schema.org such as symptoms, health benefits, and misconceptions about certain types of food. We add a separate column related to nutrition information in Table 1. Though the nutrition information is implicitly available for recipes, menu items, food items, dietary supplements, and ingredients, we wanted to prevent redundancy which would have occurred by listing individual nutrition components under each entity column, unnecessarily leading to increased table length. We noticed that % daily value, vitamin, mineral, and electrolyte content were not captured in schema.org and have included these components based on the competency questionnaires.

We are in the process of designing our own schema for allergens, taste, and health effects since we feel the existing information is inadequate. We present a comprehensive list of entity components and more importantly analyze the interdependencies and intricacies of each component. Our schema serves as a benchmark for capturing food-related data and its inter-dependencies and is instrumental in collecting data from multiple sources for building the World Food Atlas.

7 CONCLUSION AND FUTURE WORK

We develop a world food atlas for food navigation to solve the person-entity-context food recommendation problem. We review current food atlases and knowledge graphs and critically analyze their limitations. Apart from critiquing existing work, we propose a novel world food atlas architecture platform that congregates data from multiple streams and multiple stakeholders. Our novel world food atlas schema weaves a canvas around the interconnected web of food components for food-related user queries. The atlas has the potential to generate personalized location-based food data that can be used by individual users, food services, and healthcare providers to improve personal health, increase food supply chain efficiency and allow targeted healthy food recommendations.

Over time, we seen potential for the schema to expand to include more interconnected components related to food and health. While collecting data from multiple sources, we came across duplicate and redundant data. By incorporating and expanding our standardized data collection and specification pipeline, there is scope for decentralized data processing and management from different contributors. In this way, it is possible to handle large-scale data and ensure scalability of the platform. A vetting process for verifying the validity of data sources, processing user-generated data, and preserving privacy is essential to maintain and increase the robustness of the world food atlas platform. Also, we have to deal with the problem of missing data through predictive analytic approaches using machine learning. We strive towards automatic database expansions and decentralized blockchain approaches for empowering individual users, organizations, and different stakeholders. Validating responses from the world food atlas is essential to ensure the accuracy of data provided to users. We also intend to expand the number of components of the world food atlas schema. We are working towards creating taste schema and health effect schema through consultations with dietitians and nutritionists. Our world food atlas will be a hub for all food-related atlases and be a one-stop solution for all food-related queries.

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A QUESTIONNAIRE TO CREATE WORLD FOOD ATLAS SCHEMA

We present the list of potential questions nutritionists, physicians, and dietitians from Stanford University, USA have for the World Food Atlas platform.

Category 1 - In this category, the main goal is to understand a user's physiology, psychology, their willingness to pay for food (healthy and unhealthy), and how much people enjoyed eating their food.

- What did you eat?
- Did you cook it or did you buy it?
- From where did you buy it?
- Did you enjoy this dish?
- Did you do any activity before or after eating this dish? How long and what kind of activity?
- Do you measure your blood glucose response to meals? If so, what was your blood sugar 2 hours after your meal?
- How many servings did you eat?
- How much did this dish cost?
- What else did you think about this food? What did you like or dislike about this food in particular?
- Did you take any medication with this meal? If yes, what kind and how much?
- Did you inject insulin before this meal? If yes, how many units?
- How are you feeling today? (Scale 1-5, perhaps)
- Are you experiencing any changes to your health? If so, are you experiencing any of the following?
  - Numbness, tingling
  - Frequent urination
  - Blurry vision
  - Sudden weight loss or weight gain
  - Chest pain
  - Back pain
  - Dizziness
  - Other (please explain)

Category 2 - In this category, questions related to the nutrition content of food and associated health benefits are asked so as to empower researchers and food producers to make food that is more optimized for people's health.

- What is the food's shelf life?
- How is the food prepared? (How does steaming, baking, frying, etc. alter nutrition content?)
- Does this food have known health properties?
- What is this food's pre-, pro-, and post-biotic content? (Important for those trying to improve gut health)
- What is this food's fatty acid profile? (e.g., what is its ratio of omega 6 to omega 3 fatty acids?)
- Does this food have known disease prevention properties?
- Is it a known cause of food intolerance?
- Are there pickled/fermented versions of this food item, and what are its health benefits?
- What impact does the food have on insulin levels?
- What is the glycemic index of a food item?
- What is the food's insulin index?
- Effect on fasting (Does this item disrupt a fast? For instance, some foods like black coffee, unsweetened tea, and foods in the Fast Mimicking Diet do not break a fast)
- Effect on triglycerides (Does it lower or increase triglycerides in the body?)
- Effect on pre-existing diseases
- Distribution location (Are there pathogens/allergens on the site?)
- Ingredient interactions (Are there specific compounds in this item that interact with compounds in other ingredients or drugs? For example, grapefruits and statins.)
- What is the effect on your cardio-metabolic health? (Does this food item have a known link to heart disease, chronic heart failure, diabetes, kidney disease, etc.?)
- What is the vitamin, mineral, and electrolyte composition of the food?
- What effect did the food have on your mental and physical health?
- What effect did the food have on your sleep and stress?
- What effect did the food have on your skin?
- What effect did the food have on your optical health?
- Where it was grown/raised/produced/obtained? (e.g., the effect of climate, soil content on nutritive content)