# Inspiration from Systematic Literature Reviews to Predict the Future of Food Services in Smart Cities

Anaisa Lucena
*I3N & Physics Department*
*University of Aveiro, 3810-193*
Aveiro, Portugal
anaisalucena@ua.pt

Ana Sofia Freitas
*Wish and Cook*
Aveiro, Portugal
anasofiafreitas@wishandcook.com

Antonio Luis Ferreira
*I3N & Physics Department*
*University of Aveiro, 3810-193*
Aveiro, Portugal
alf@ua.pt

Fernao Vistulo de Abreu
*I3N & Wish and Cook*
Aveiro, Portugal
fva@wishandcook.com

***Abstract*—The fifth industrial revolution is set to transform the industry-consumer relationship, particularly impacting the urban-based food services sector. To gain insights into its potential trajectory, a systematic literature review employed a modified Non-negative Matrix Factorization algorithm to quantitatively identify emerging research trends and existing work in smart cities, food, nutrition, and artificial intelligence. The study revealed that smart cities will facilitate automatic connections between consumers, farms, restaurants, and health systems. With automated management systems triggered by meal orders, waste reduction, minimized environmental logistics costs, customization of consumer preferences, and personalized health recommendations can be achieved.**

***Keywords-personalized nutrition; food services; smart cities; artificial intelligence; NMF.***

## I. Introduction

The upcoming fifth industrial revolution will be characterized by an unprecedented level of automation [1].

Due to its primarily urban-based operations, the food services sector is expected to be highly impacted. To gain insight on how this sector can evolve, a search on papers relating smart cities and food services was conducted. However, given the limited number of papers available, two complementary literature reviews had to be devised.

This article is structured as follows: first, in Section II, a description of the quantitative literature review methodology is introduced. Then, in Section III, the topics that emerged from this analysis are presented and, finally, in Section IV, the implications of the findings are discussed. These are summarized in the concluding section of the article, Section V.

## II. Methodology

### A. Information gathering

After performing a number of searches, it was found that two complementary searches returned more than 100 articles. One search used the *PubMed* MeSH term ”*nutritional physiological phenomena*”, together with the expression ”*artificial intelligence*”. This search returned 157 articles. The second search used the *Web of Science* and the keywords *(”smart cities” or ”smart city”) and (nutrition or food)*. This search returned 381 articles. For each article, the title, the complete abstract and the year of publication (see Fig.4) were registered and later processed and analyzed.

### B. Data Processing

To make a quantitative literature review, computational Natural Language Processing (NLP) [2] techniques were applied on titles and abstracts. This involved converting every letter to lowercase, removing non letter characters, tokenizing the text (in order to analyze words individually), removing stop-words (the most common English words, such as '*the*', '*or*', '*what*', etc.) and stemming (reducing inflected words to their word stem or root form, i.e. the words '*simulation*', '*simulator*' and '*simulate*' can all be reduced to their stem '*simul*'). In addition to ignoring English stop-words, 647 articles were collected from *Semantic Scholar* using the keyword ”*biotechnology*”. Since biotechnology is a scientific topic, the goal was to analyze the relative frequency of words in typical scientific articles, and to remove scientific stop-words without removing words specific to the areas under analysis. With this collection of scientific articles, the frequency of occurrence of each word (3133 and 5336 in the *PubMed* and *Web of Science* searches, respectively) was compared to its frequency of occurrence on the selected titles and abstracts (regarding the *Semantic Scholar* search). Then, the 100 words that appeared more frequently in the selected titles and abstracts than on the other articles (related to biotechnology) were selected. This eliminated words that appear frequently in scientific texts (such as prove, demonstrate, experiment, etc) but do not provide information for this analysis.

### C. Modified Non-negative Matrix Factorization algorithm

In order to identify the different thematic areas for each search, a Non-negative Matrix Factorization (NMF) algorithm was used. This algorithm finds an approximate factorization of the input matrix $V$ into two other non-negative matrices [3], $W$ and $H$, such that $V \approx WH$. In this case, the input matrix $V$ was defined as a binary matrix, where each row is associated with an article and each column is associated with one of the 100 words. Each entry is either 0 or 1, depending on whether the word is present. The NMF algorithm compresses the information contained in the $n \times m$ input matrix $V$ because $W$ and $H$ have smaller dimensionality, respectively $n \times k$ and $k \times m$. Therefore, each line in $V$, a vector containing the pattern of words in an article, will be decomposed as a linear combination of the corresponding line in $W$ and the matrix $H$, which has a small number of lines ($k$). Each line in $H$ can be seen as a topic; entries of $H$ with higher values highlight the most relevant words in that topic.

Given that the number of articles used in these searches is relatively small (in statistical terms), some topics (lines in the $H$ matrix) have one entry (word) dominating all others, as shown in the example in Figure 1. There, the word '*propos*' has a significantly higher value than the others. This would mean that the presence of the word '*propos*' would be enough to associate it to a topic, which is a typical example of over-fitting due to the small number of articles used.

To overcome this problem, an iterative formulation of the NMF algorithm was developed such that whenever the weight associated with a word in the matrix $H$ represents more than $20\%$ of all the weights in the same topic, the corresponding entry for that word in the input matrix $V$ is decreased by $1\%$, as detailed in Figure 2.

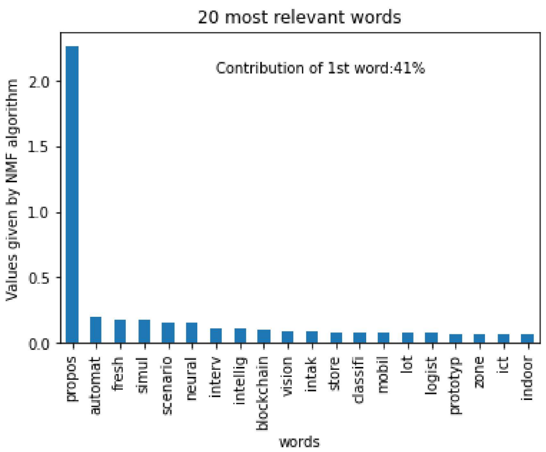


Figure 1: Bar chart representing the 20 words with the highest values for a row of the H matrix of the NMF algorithm before being modified (from the articles in Web of Science searches).

The application of this algorithm in the example in Figure 1 changed the values of the highest weights in matrix $H$ as shown in Figure 3.

Now, a larger number of words is necessary to define a topic. Furthermore, the semantic consistency of the several words defining each topic shows that this procedure produces much more meaningful results.

## III. RESULTS

Table I shows the 15 most common words on both searches. These words, although related, are not coincident, showing that the two searches are not redundant.

**Algorithm 1** Modified NMF

$N \leftarrow$ number of articles
$V \leftarrow (N \times 100)$ binary matrix where $V_{ij} = 1$ if article $i$ contains word $j$
$W, H \leftarrow$ NMF decomposition of $V$
$l \leftarrow$ list of the words where $max(H_i)/\sum H_i > 0.2$, for each topic $i$
**while** $l$ is not empty **do**
  **for** every article $a$ **do**
    **for** every word $w$ in $l$ **do**
      $V_{aw} \leftarrow$ decrease $1\%$
    **end for**
  **end for**
  $W, H \leftarrow$ NMF decomposition of $V$
  $l \leftarrow$ list of the words where $max(H_i)/\sum H_i > 0.2$, for each topic $i$
**end while**

Figure 2: Algorithm of the modified NMF

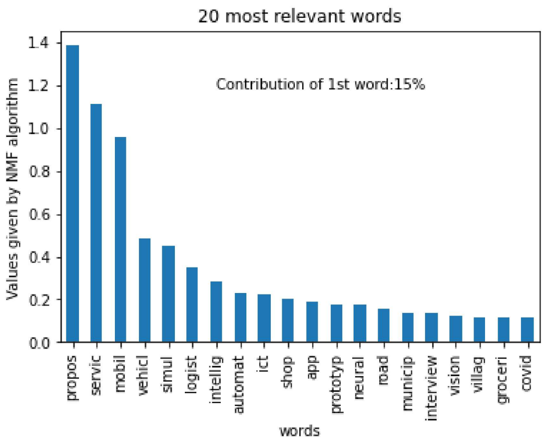


Figure 3: Bar chart representing the 20 words with the highest values for a row of the H matrix of the modified NMF algorithm (from the articles in Web of Science searches).

The number of articles published per year on each search is shown in Figure 4. The growth in activity in recent years, on both cases, demonstrates the significance of these topics to the scientific community.

TABLE I: MOST COMMON STEM WORDS IN BOTH SEARCHES PERFORMED, SORTED FROM MOST TO LEAST COMMON.

| Search | 15 Most Common Words |
|---|---|
| *Web of Science: smart cities* and (*food or nutrition*) | urban, water, iot, propos, servic, sensor, internet, infrastructur, plan, mobil, intellig, spatial, scenario, store, fresh |
| *PubMed: nutritional psysiological phenomena* and *artificial intelligence* | diet, artifici, patient, intellig, dietari, machin, intak, ai, imag, behaviour, person, intervent, diabet, algorithm, glucos |

In Table II, the 6 themes identified for each search are summarized.

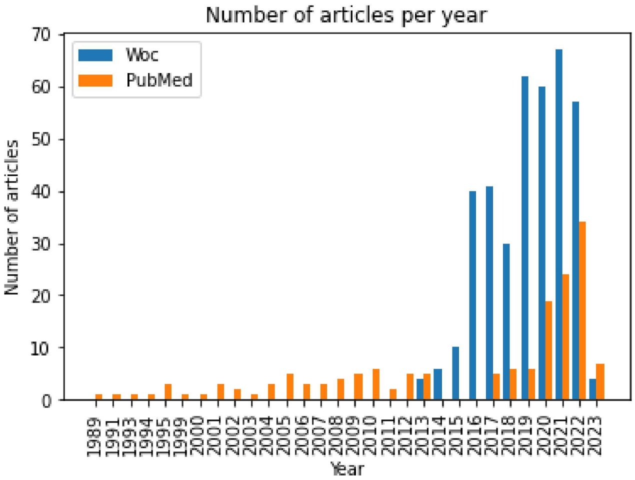


Figure 4: Temporal distribution of the articles fetched.

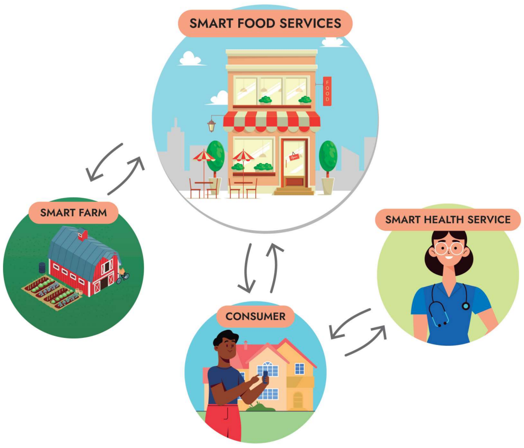


Figure 5: Illustration of the network interacting with future smart food services.

## IV. Discussion

Analysis of Table II reveals that both searches were coincident on some topics - for example, optimization methods to design nutritional plans, WoS5 and Pubmed3 - but provide additional insights on others. This demonstrates that there is consistency between the methods and also complementarity. Furthermore, as both searches provide topics related to optimization methods to design nutritional plans, it is possible to conclude that nutritional plans using the help of artificial intelligence are likely to emerge in smart cities.

A thorough analysis of Table II provides important insights on how food services may evolve in smart cities. For instance, WoS1 emphasizes the importance of developing a direct connection between farms and consumers, to reduce food insecurity, which is especially relevant for fresh food options (a concern also highlighted in WoS3) and to promote sustainable city expansion and social-wellbeing. Therefore, food services creating a direct link between farms and the consumers' table could be perceived positively. In Figure 5, continuous interactions with farms allow smart management for storage and deliver. Food services interact with consumers providing suggestions on meals according to the information they receive from the consumer that is interacting with health services. The consumer send medical information through tools and sensors to the health services that will online monitor and prescribe the best nutritional plans.

Topics WoS5 and Pubmed1 highlight problems related to self-report food intake. Indeed, children and adolescents are unable to self-report food intake without caregivers [19] and even trained individuals have difficulties in estimating food portions accurately [20]. Solutions with sensors (body sensors, cameras, etc) and artificial intelligence could contribute to monitor and help control food intake, helping to develop better food prescriptions, better disease prediction, and improved prevention strategies.

Several diseases or health conditions could benefit from interaction with future food services. For instance, accurate food intake monitoring could help control obesity and diabetes (WoS5 and Pubmed1, Pubmed2 and Pubmed3). However, far-reaching outcomes could be achieved by combining biomedical parameters, nutrigenetic, nutrigenomic information, food mapping and consumer behavior (PubMed5).

This could have an impact in other diseases, such as hypertension, hypercholesterolemia, hepatic steatosis and real insufficiency, to mention only a few.

## V. Conclusion and Future Work

This literature review provides an insight on how future smart cities, through the establishment of a network made of various participants interconnected with feedback loops, will facilitate the development of innovative food services.

Thanks to advancements in technology, consumers will be able to leverage sensors and apps to track their health status, customize their meal preferences with the help of online health professionals and bots, placing orders that align with their dietary requirements. Additionally, food services will prioritize resource optimization and encourage consumers to select options that reduce food waste.

Furthermore, food services can have a significant impact on the future farming, with automated kitchen inventory systems sending real-time storage updates to farms and facilitating the delivery of produce based on demand projections. This symbiotic relationship between food services and farms will improve the efficiency and productivity of both industries on a day-to-day basis.

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TABLE II: CONTENT TABLE FOR THE TOPICS OBTAINED.

| Topic | Type of Solution | Example | Problem Addressed |
|---|---|---|---|
| WoS1 | Urban agriculture | Human expansion into Asian highlands [4] | Food insecurity reduction, cities expansion, sustainability, social-wellbeing |
| WoS2 | Blockchain for medical sector | Application of blockchain for drug traceability, remote patient monitoring and medical records management [5] | Security of records and quality improvement |
| | Big data for computer optimization method for the food nutrition formula | Computer optimization of food nutrition formula based on the consideration of adaptive genetic algorithm [6] | Nutrition formulas optimization |
| | Big Data for humidity sensors and automatic water irrigation scheduling | Smart water metering system sensor with new hybrid IoT [7] | Water resources optimization in agriculture |
| | Big Data for home | IoT based on automation and security systems [8] | Security at home |
| WoS3 | Food conservation methods and food quality evaluation | Computer vision system that detect ammonia content in lettuce, discriminating the marketable samples from the waste [9] | Storage time increasion, food waste reduction and waste avoidance of the good quality food |
| WoS4 | The second life of solid materials, food or water | Meal Matchup is an open source that give access to food closed to waste [10] | Resources optimization |
| WoS5 | Application of AI in nutrition sector, such Predicting/managing diets for patients | Internet-based application for research on essential nutrients [11] | Health professionals work optimization |
| | Application of AI in nutrition sector, such body sensors that detect chewing or automated image processing | On-body sensor that detect chewing and connect to food intake [12] | Food intake collection with more accuracy |
| WoS6 | Neural networks for prediction of intestinal absorption | Computational models for drug inhibition of the human apical sodium-dependent bile acid transporter [13] | Better drug and food prescription and health monitoring |
| PubMed1 | Body sensors that detect chewing or automated image processing that recognize the food and their quantity | The goFOOD Lite App that, through a photo, detect the ingredient and the meal and convert into nutritional information of the food intake [14] | Food intake collection with more accuracy |
| PubMed2 | Tools to manage glucose intake, glucose blood levels and insulin administration | PSECMAC - Positive evaluation of an intelligent insulin schedule to accurately capture the human glucose-insulin dynamics and manage glucose without meal announcement [15] | Glucose prediction and management in type-1 diabetic patients |
| PubMed3 | Artificial intelligence personalised nutritional plans | Physical Activity and Diet Artificial Intelligence Virtual Assistant that detect moments of dietary intake, estimate nutritional intake and generate personalized/precision nutrition recommendations [16] | Health profissionals help to plan personalized nutritional plans and helps general people to have access a personalized nutritional plan |
| PubMed4 | Machine learning algorithms | The case of generate a "food map" with potential anti-cancer properties [17] | Prediction, prevention and/or classification of various diseases or conditions (such malnutrition) |
| PubMed5 | Analyses of nutrigenetic, nutrigenomic and consumption behaviour | Implementation of Nutrigenetics and Nutrigenomics Research and Training Activities for Developing Precision Nutrition Strategies in Malaysia [18] | Excess weight and obesity |
| PubMed6 | Neural networks for prediction of intestinal absorption | Computational models for drug inhibition of the human apical sodium-dependent bile acid transporter [13] | Better drug and food prescription and health monitoring |

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