Food Informatics

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Food Informatics is the collection, preparation, analysis, and smart use of data from agriculture, the food supply chain, food processing, retail, and smart (consumer) health for knowledge extraction to conduct an intelligent analysis and reveal optimizations to be applied to food production, food consumption, for food security, and the end of life of food products.

Keywords: Food Informatics ; Internet of Things ; Precision Agriculture ; Internet of Food ; Food Computing

1. Introduction

Scientists have been alerting the world about climate change for a very long time, such as the World Scientists' Warning to Humanity from 1992 and the more recent World Scientists' Warning to Humanity: A Second Notice in 2017. However, it required Greta Thunberg and Fridays for Future to raise awareness about climate change and protect the environment and society. One aspect that, on the one hand, impacts climate change but on the other hand is also highly influenced by it, is the production of food. Roughly 11% of the Earth's population was unable to meet their dietary energy requirements between 2014 and 2016, representing approximately 795 million people [1]. On the contrary, the food production for the population of industrial nations, especially, highly contributes to climate change due to a meat-focused diet, with the expectation of seasonal fruits throughout the entire year as well as a high waste of food [2]. Both situations will become more complex in the next decades as the global population is predicted to grow to 10 billion by 2050 according to the United Nations [1]. This might increase the number of people with insufficiently satisfied dietary energy requirements. The increasing welfare in emerging countries will lead to more people adopting the resource-demanding nutrition of the industrial nations.

Traditional food production approaches will not be able to deal with those issues sufficiently; hence, novel approaches are required. Especially the integration of current research advances in the Internet of Things (IoT) seems to be promising in supporting various aspects of food production including farming, supply chain management, processing, or demand estimation. Whereas a commonly accepted definition of IoT is not present in the literature, it is agreed that IoT refers to connected computational resources and sensors which often supplement everyday objects. The sensors support the collection of data that can be analyzed for identifying changes in the environment and the IoT system can react to accommodating those changes. Procedures from Artificial Intelligence (AI)—the idea that machines should be able to carry out tasks in a smart way—and Machine Learning (ML)—techniques for machines to learn from data— can complement the analysis and system controlling process in IoT systems. The actions of analyzing and controlling the IoT systems are also named as a reason for adaptation [3]. The purposeful application of those methods can complement and optimize the existing processes. The research in this field is distributed across several domains, such as Precision Agriculture, Smart Farming, Internet of Food, Food Supply Chain Management, Food Authentication, Industrial IoT (IIoT)/Industry 4.0 for food production, Food Safety, Food Computing, or Smart/Pervasive Health. Often, those concepts overlap and are not completely distinguished.

2. Delineation of Concepts

The production of food is a highly complex process. On the one hand, there is a high diversity in the combination of ingredients and intermediaries with many dependencies, for example, in the order of processing. Further, by-products, side-products, or co-products might arise, such as buttermilk when producing butter to mention just one example. On the other hand, food has hygienic, olfactory, sensory, or preserving requirements. In general, the food production process can be divided into several phases:

- Agriculture: Production of ingredients/food.
- Logistics: Transportation of food while obeying hygienic constraints.
- Processing: Processing of ingredients to food products in an industrial process.
- Retail: Selling of food.

- Consumption: Humans consume the food.
- Food Waste Handling: Intelligent forms of handling food waste and disposal improves sustainability.

Food production may benefit from Industry 4.0 approaches. Predictive maintenance can lead to a production increase, especially as machine defects in the context of food production have a more serious impact due to the perishability of ingredients in contrast to tangible product elements in the production area. Further, the flexibility of Industry 4.0 approaches can help to facilitate the production of individual, customized food articles. Luque et al. review the state-of-the-art of applying Industry 4.0 technology for the food sector and propose a framework for implementing Industry 4.0 for food production centered around the activities of the supply chain [4].

Third, some research streams are related. Smart and Precision Agriculture address the agricultural process and can be integrated to maximize their benefits. The Internet of Food research stream overlaps with food supply as it addresses the monitoring of food. Further, as monitoring of food is an inevitable element for Food Authentication, the Internet of Food is also related to Food Authentication and food safety. Lastly, Food Computing and Smart Health overlap in their purpose as well as some methods, for example, data extraction from pictures captured with smartphones.

3. A Revised Definition of Food Informatics

The understanding and motivating Food Informatics as a mainly data-driven perspective. This includes the development of tools and technologies to enable the application of ontologies for sharing knowledge specific to the food production process [5][6][7]. Similarly, according to some opinions [8][9], Food Informatics deals with collecting information and documenting the health and medicine-related information. On the contrary, it [10] also include the reaction on the analysis of the collected information while limiting the application to the end-users to eHealth for the prevention and management of overweight and obesity.

The large diversity of definitions demonstrates that the meaning of the term “Food Informatics” has not yet converged to a consensus. Still, all definitions at least focus on the data collection and use of the data related to food. However, while some works focus on food production [11][5][12], others highlight the importance of integrating consumers [8][10]. This shows a large diversification and spans almost the whole process of food production. Additionally, the application of the collected information differs from providing ontologies [11][5], integrating technology for data collection [5], the use of informatics to analyze the collected data and reacting accordingly [8][10], or even integrating other natural science disciplines for information retrieval [12]. To summarize, no currently available definition for Food Informatics covers all relevant aspects.

The existing definitions target the phases of food production and data management as well as Smart Health. As the production of food is an interplay of many different processes in agriculture, production systems, supply chain management, and Smart Health with obvious interdependencies, it was proposed to also include the data/information acquisition from the very beginning; hence, during crop and livestock production (smart agriculture), and to also take information collection for logistics and transportation into consideration. The entry deems a span over the entire process important, as issues in one process step might impact other process steps. For instance, insufficient handling of food during transportation can negatively impact the food quality for the customers. Accordingly, a holistic information perspective is important. Various technologies can support the collection of such information, especially IoT technology. Furthermore, the analysis of the collected data can highly benefit from (Deep) ML and data analytics techniques. Approaches from the research domains concerned with adaptive systems, for example, self-adaptive systems [3], self-aware computing systems [13], or Organic Computing [14], can support the implementation of mechanisms that allow for adequate reactions according to the analyzed information. A robust self-reconfiguration to react to unexpected events, such as machine defects in the food production facilities, constitutes an example of that. However, due to the hygienic, taste-related, or legal constraints, the area of food production has many domain-specific requirements that must be satisfied. Hence, a proposal is that the customization of computational approaches optimized for the specifics of the food domain. This should be the central task of Food Informatics. To reflect all considerations from above, a new definition is suggested:

Food Informatics is the collection, preparation, analysis, and smart use of data from agriculture, the food supply chain, food processing, retail, and smart (consumer) health for knowledge extraction to conduct an intelligent analysis and reveal optimizations to be applied to food production, food consumption, for food security, and the end of life of food products.

4. Food Informatics in Practice: Today and Tomorrow

Food Informatics can provide a powerful framework for supporting the adaptivity of intelligent production systems which are customized to the specifics of the food industry. Furthermore, it can support the integration of emerging technologies that can foster the individualization of food items, such as additive manufacturing via 3D printers [15].

Although it is clearly understood that such production delays imply monetary losses in the production of normal goods, the consequences of such unexpected production downtimes are even worse for the production of food due to its perishability. Accordingly, the utilized prediction and forecasting methodologies demand for customized algorithms and, thus, advanced development and domain knowledge.

Recommendation systems (such as [16]) can aid the process of automatic identification of the most adequate forecasting algorithm fitting the underlying data patterns. The selection of the most appropriate algorithm might then be combined with automatic algorithm configuration or hyperparameter tuning [17] for optimizing the parameter setting of the algorithm to be utilized. Food Informatics should contribute here by means of conducting research in both areas. That is, to provide predictive maintenance automatically optimized to the specific requirements of food production, for example, by focusing on forecasts of machine defects with time horizons that consider the foods' perishability and cooling requirements. Further, those recommendation systems can be re-used for other forecasts, for example, forecasting the transportation time or the demand for a specific food.

A sensible trade-off between a product in stock, as well as a purely demand-driven production, could be the integration of demand forecasting by identifying food consumption trends. Research streams as Food Computing [18] and Smart Health [19] can contribute to the analysis of consumer behaviors and forecasting of food demands due to their methods for information extraction. Embedding such demand forecasts into a feedback loop can optimize the various aspects from food production to consumption behavior and eventually reduce food waste. Coupled with adaptive food production systems as outlined above, this constitutes a promising way for achieving sustainable food chains.

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