Cornucopia: The Concept of Digital Gastronomy

GENERAL ARTICLE

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Amit Zoran and Marcelo Coelho

ABSTRACT

The authors present a new concept of *digital gastronomy*—Cornucopia, a futuristic cooking methodology based on digital technologies. They discuss how they have merged kitchen tools with science fiction and actual technologies to create this new design space for gastronomy. The Virtuoso Mixer, the Digital Fabricator and the Robotic Chef were conceptualized to enable more flexibility and control over each of the most important elements of cooking: mixing ingredients, modeling food shapes and transforming edible matter from one state to another. The authors discuss related work and ideas, present their designs and propose their vision for the emerging design space of digital gastronomy.

Technology and gastronomy, the practice of cooking and eating food, have evolved together for thousands of years: Every ethnic group has developed unique dishes and food cultures, creating tools from accessible materials such as wood, stone, clay and metal [1]. Patterns of trade and migration brought technologies, ingredients and rituals to new places, shaping local economies and perspectives on the environment. The image of food and ingredients is rooted in the cultural connection between technology, mythology and nature [2,3]. This link is apparent in the rituals and ceremonies that evolved around meals, the narratives associated with ingredients and dishes, and health constraints on what we eat. In addition, our image of technology has continued to evolve since the first day man held tools in his hand. Today, the media plays an important role in providing and transforming these narratives, making the dreams of few the news of many [4]. Technological narratives thus have an increasing influence on the perception of the kitchen of the future and therefore on the shape it will eventually take.

The history of gastronomy is only one aspect of human creation: From ancient metaphysics, alchemy and native magic to modern science, humanity has always tried to understand the environment in order to control it. In this context, the desire to control matter—that is, change its properties and manipulate its shapes—and the narratives associated with this desire are entrenched in modern culture. Consider this quote from Isaac Asimov's *Foundation:*

> This . . . is a small device I constructed myself. . . . It is atomic in nature. . . . With this machine . . . I can turn the iron you discard into gold of the finest quality: it is the only device known to man that will take iron—the ugly iron, your veneration, that props up the chair you sit in and the walls of this building—and change it to shining, heavy, yellow gold [5].

This futuristic vision appears when Ponyets, an outer-space trader, presents his product to a prospective buyer. Asimov, of course, played with an ancient metaphor: Creating gold from cheaper materials was an old dream of humanity, associated mostly with alchemists. The quest for gold concerns the big questions of nature, being the most prestigious of all matter-transformation efforts. He who can create gold can create all. And although creating gold is still a distant dream, our ability to manipulate matter and shapes is increasing. Ponyets, however, does not craft the gold through alchemy: An automatic machine does it for him.

While creating gold may be a utopian dream, similar concepts of the manipulation of matter and energy appear in other fiction. For example, In "Star Trek: The Next Generation" [6], the Replicator is a machine that generates matter from energy, accepting pre-stored shapes, mainly used to synthesize meals. Visually, this looks like magic: The food appears out of nothing, fulfilling the archetypical image of creation. The vision of Star Trek was not new: Similar concepts had already appeared in earlier films such as *Kitchen of Tomorrow* [7] and *1999 A.D.* [8], in which the concept of an automatic, programmable future kitchen was offered. The last few years have brought an increasing amount of conceptual work visualizing new ideas for similar concepts.

Philips Design, the design division of the international Dutch electronics corporation Philips, has investigated several concepts dealing with future gastronomy [9]. These concepts—the Diagnostic Kitchen, Food Creation and Home Farming—represent an unconventional approach to reimagining the way we eat and get our food in the future. The Food Creation project is a modern interpretation of Star Trek's Replicator, based on molecular gastronomy. A similar concept developed by Nico Kläber for the Electrolux Design Lab competition, that of a 3D food printer, is fascinating and beautifully rendered [10]. This offers a virtual image of a machine that would fulfill the vision of an automatic, controllable, programmable process that can manipulate the form and substance of edible matter. What, however, is the motivation for these fictional creations? What is the cultural drive for the concept of automating domestic cooking?

The Evolution of Digital Gastronomy

Since World War II, Americans have been cooking progressively less, as a result of the development of a huge food industry mass-producing food products, especially since the 1950s and 1960s. This changed the way food is produced, distributed, stored and used. While these developments were basically commercial in nature and had very little relevance for nutrition, it does not mean we lost interest in food culture [11]. Yet we are

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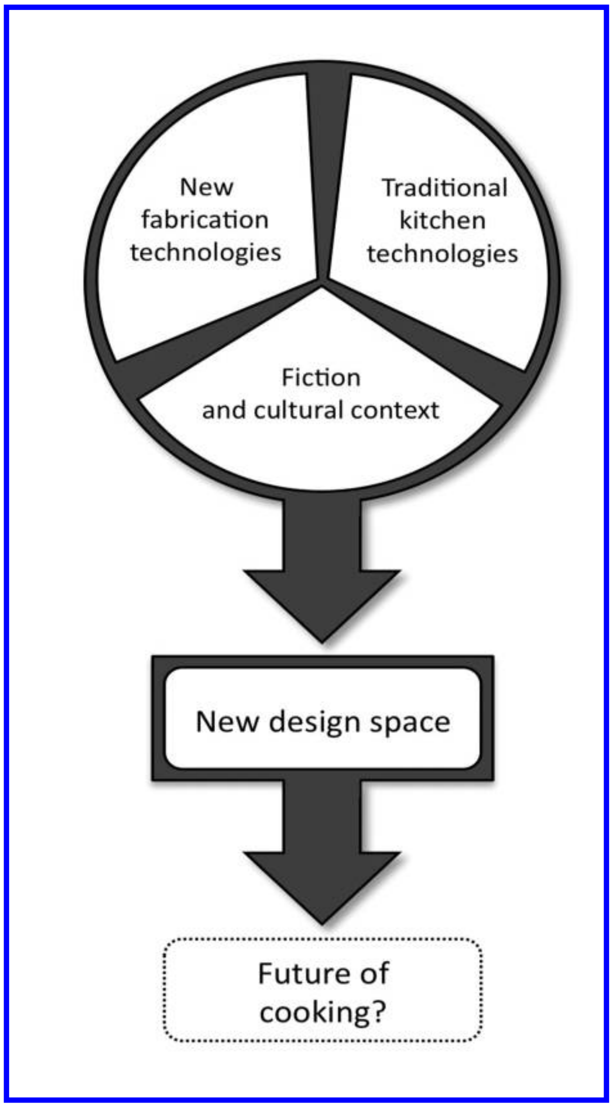

Fig. 1. The development of a new design space. (© Amit Zoran)

no longer interested in using traditional tools to craft meals for ourselves. Thus, future gastronomy considers a different understanding of food, based not simply on economic drives but on a much finer understanding of the short- and long-term effects of different diets on people and the environment, with the means to enable personal creativity and control in the preparation of food.

The *slow food* movement faces these same challenges with a traditional approach, promoting education, fairs and events to support food biodiversity and hoping by this means to "save the countless traditional grains, vegetables, fruits, animal breeds and food products" [12]. We believe that, side by side with the slow food and similar movements, which rely on historical experience and knowledge, there is also a place to consider the development of new technologies to help compensate for the negative effects of mass production. Today, even as digital media is transforming society, the fundamental technologies we encounter in the kitchen provide only incremental improvements to the tools we have been using for hundreds of years. Thus, is it not time to consider a technological revolution in our traditional cooking process?

Searching for a new word to describe these explorations, we first looked at Brillat-Savarin's work *The Physiology of Taste,* published in 1825, which broadly describes gastronomy as "the intelligent knowledge of whatever concerns man's nourishment." Savarin continues:

> Gastronomy is a chapter of natural history, for the fact that it makes a classification of alimentary substances. Of physics, for it examines their properties and qualities. Of chemistry, from the various analysis and decomposition to which it subjects them. Of cookery, from the fact that it prepares food and makes it agreeable. Of commerce, from the fact that it purchases at as low a rate as possible what it consumes, and displays to the greatest advantage what it offers for sale [13].

Another source of inspiration is *molecular gastronomy*, a new cooking approach developed over the past 20 years. Molecular gastronomy focuses on the chemical processes that occur during cooking to create new flavors and aesthetics [14], such as mille-feuilles, salads, foams and powders from unexpected ingredients using revolutionary techniques. A gastronomy expert, Hervé This, differentiated the field from the more traditional food science, which deals primarily with the composition and structure of food, by clarifying that molecular gastronomy "deals with culinary transformations and the sensory phenomena associated with eating" [15]. Rather than understanding the physics of food, the focus here is on gathering knowledge about the cooking process, demystifying some of its old techniques and, as a result, opening space for new avenues of exploration and creativity.

We define our term, *digital gastronomy*, in similar holistic terms. Our focus is on how digital fabrication technologies can be integrated into the kitchen so that they can later influence our eating experiences and the process of cooking by playing a new role in food's preparation, culture, economy, physics and chemistry. At the center of this vision is the creation of a new design space that goes beyond the experience of taste to encompass all aspects of gastronomy—visualizing the way we can manipulate food digitally.

A New Design Space

In response to this vision, we present Cornucopia, our concept for futuristic kitchen machines with new digital cooking interfaces inspired by a novel digital gastronomy. We start by investigating the conceptual ways digital technologies can influence the various stages of cooking and then present and discuss our three concepts of digital gastronomy. Our work is part of a new design space that arises from novel fabrication technologies and traditional cooking tools and merges with cultural narratives of matter creation and manipulation. This design space may pave the way for future development of new technologies (Fig. 1).

Thus, we present a technological vision that renders the automatic process of shaping edible matter into a practical design format, relying on existing technologies. To achieve this, we developed three conceptual designs (not actual working machines) for digital gastronomy with different functionalities. We have done this to illustrate the technical possibilities these concepts offer (rather than to claim these machines solve all the current problems of the food industry), to discuss the ethnographic context and to show how these new narratives of gastronomy reveal our image of technology.

Outside the Kitchen: Digital Fabrication

Over the past 50 years, digital tools have dramatically altered our ability to design the physical world. For example, advances that have taken place in graphics software and hardware have gone beyond the domain of specialists alone and have reached our personal computers. However, the use of some tools, such as 3D printers, has—until now—remained restricted to a few. Recent advances promise to change this. In the last few years, the price of 3D printers has fallen dramatically, and several do-it-yourself (DIY) technology groups have started developing and making their open-source 3D printer designs accessible to anyone interested in modifying or building these machines at home.

Digital fabrication technologies can be grouped under two main categories: subtractive processes and additive processes [16]. Subtractive approaches use drill bits, blades or lasers to remove substances from their original sources, shaping the desired 3D object. Additive processes, on the other hand, use an array of techniques for depositing progressive layers of material until a desired shape is achieved. While subtractive technologies, such as milling, are commonly used to create accurate casting-molds for mass production, additive technologies are still limited in their abilities and are currently used for rapid prototyping. It is reasonable to assume these two processes will be available to the public in the future, improving our ability to easily create forms and designs. As these machines and fabrication techniques become commonplace in our homes, they will drastically affect the types and quantities of objects we own, altering our creative possibilities [17]. In the context of this paper, it is important to consider how digital fabrication tools will influence our cooking and dining culture.

In the Kitchen

Cooking, then, is both a subtractive and an additive process. It is also primarily transformative: Ingredients are combined, heated and cooled, and chemical reactions transform these ingredients into new ones in the process of creating new shapes, textures and flavors.

Today's kitchens are already outfitted with digitally controlled electronic tools: Refrigerators can produce ice on demand; ovens can configure temperature and cooking time based on weight and the kind of food cooked; and coffee machines can be programmed to prepare coffee for you before you get out of bed. Thus, the practical vision of digital gastronomy is underway. Researchers have been exploring ideas for future kitchens for many years. Relevant examples are the use of computer numerical controlled (CNC) laser machines to create 3D sugar structures [18] and DIY 3D printers to model 3D objects from edible ingredients, such as cheese and chocolate [19].

Computer-controlled machines have started a new revolution in design, allowing designers to manipulate forms and materials with increased and previously unimaginable capability and efficiency. This versatility, applied to cooking, can enable users to develop new flavors, textures, scents and shapes to create entirely new eating experiences that would be difficult to achieve through traditional cooking methods. For example, using traditional methods, it would be impossible to create lasagna dough in a variety of new forms and designs or to apply scientific principles to radically recon-

Fig. 2. The ingredients-combination machine—The Virtuoso Mixer. (© Amit Zoran)

struct the substance of our dishes (as is the case in molecular gastronomy). It is only through a true digital gastronomy that we can invent and personalize new dishes, rather than simply automate and replicate traditional ones.

In order to bring food to the realm of bits, we need to digitally describe not only its chemical content and transformation processes but also its origin, environmental impact and cultural values. An information-driven food culture can be the source of conscious and healthier choices that take place at an individual level and in concert with environmental and global concerns. Digital gastronomy, relying on digital on-line information, can easily allow us to substitute ingredients based on their nutritional content as well as our own personal and social preferences.

In the following sections, we describe a series of conceptual machines that, through different technologies, incorporate some of the possibilities described thus far, providing a glimpse of the future. Our concept designs are grouped under three different categories, which we believe lie at the heart of cooking: the ability to combine and mix different ingredients and to fully control their quantities, types and sources; the process of modeling these combinations into unique shapes with precisely defined dimensions; and finally the process of physically and chemically transforming existing ingredients into new combinations. Each design focuses on maximizing user control and creativity using a unique interface designed to fulfill specific needs. Thus, we use these machines as a platform for a conceptual investigation—as a design stage in the discussion of digital technology and the cooking process.

A Combination Machine: The Virtuoso Mixer

The process of selecting and mixing ingredients is one of the most fundamental elements of cooking. However, choosing the right materials, their quantities and the right sequence of mixing and cooking processes is not a trivial task, requiring years of training and practice.

The Virtuoso Mixer (Fig. 2) is a machine composed of a three-layer carousel capable of rotating clockwise or counterclockwise while being fully controlled by a separate digital panel. Each carousel houses eight glass containers that a user can fill with off-the-shelf ingredients. At the top layer, the containers are outfitted with weight scales as well as temperature and humidity sensors for monitoring the properties and quantity of the material they contain. Supporting these containers is a circular shelf with several types of dispensing valves to accommodate the properties of different materials. The middle layer houses eight mixing containers with several types of mixers and injection tools. The final, lower layer functions as an extrusion tray on which the final material mixture is deposited. It is outfitted with an array of thermoelectric heating and cooling elements and an insulating glass cover for quickly baking and for modifying the temperature of the produced mixtures.

The machine's interface is designed to allow users to easily and rapidly experiment with different material combinations. As ingredients move from the top to lower layers, they can be combined in precisely controlled amounts, crushed and mixed to different degrees, and eventually extruded to compile samples made of discrete layers with varying thicknesses. The large range of possible combinations allows users to quickly design, assemble and evaluate (by tasting) several ingredient combinations. The final "recipes" can eventually be saved, shared with other machines or users or simply retrieved by the same machine for the preparation of a meal. For example, in order to explore different quantities

Fig. 3. The food-modeling machine—the Digital Fabricator. (© Amit Zoran)

Fig. 4. The Digital Fabricator and its ingredient containers. (© Amit Zoran)

of sugar, flour, butter and chocolate in chocolate-chip cookies, the user can pre-program the Virtuoso Mixer to simultaneously cook all the recipes. This carousel architecture creates an efficient way to test multiple recipe variations that can generate fundamentally distinctive eating experiences while presenting subtle differences in composition.

A Modeling Machine: The Digital Fabricator

By replacing the polymers used in the 3D deposition machines with food materials, we can start to harness the potential of digital design 3D modeling and fabrication tools in cooking. To explore the convergence of digital 3D printing and food, we have developed the Digital Fabricator design concept. The Digital Fabricator is a personal food factory that brings the versatility of digital fabrication to the realm of cooking. In essence, it is a 3D printer for food, which works by storing, precisely mixing, depositing and cooking layers of ingredients.

The Digital Fabricator's cooking process starts with a broad array of food canisters, which refrigerate and store a user's favorite ingredients (Fig. 3). These are piped into a mixer and extruder head that can accurately deposit elaborate combinations of food. While the deposition takes place, the food is heated or cooled by the Fabricator's chamber or the heating and cooling tubes located on the printing head. This fabrication process not only allows for the creation of flavors and textures that would be completely unimaginable through other cooking techniques, but it also allows the user to have ultimate control over the origin, quality, nutritional value and taste of every meal.

Each canister provides instant content feedback to the user (Fig. 4). When an ingredient runs out, the Fabricator can automatically order a new canister, suggest an equivalent ingredient replacement or ask the user to do so. While this technology allows modeling and cooking, enjoying a fully controlled process, the user still has the freedom to pick the preferred ingredients from a preferred supplier, market or grocery store.

The main innovation in the Digital Fabricator is located in its printing head and cooking chamber. The head houses a multi-material mixer, which allows the user to mix and deposit small amounts of food with high precision. By this means, the Digital Fabricator can prevent waste, fine-tuning the size of the printed dish to the diet of the user, who enjoys a cooking process that is as easy as an instant meal, preserving control over the ingredients and process being used.

A Transformation Machine—The Robotic Chef

Through heat, mechanical deformations or molecular changes, the chef creates visually pleasing and delectable food. The fact that these transformations are sometimes one-way and cannot be reversed makes their use and control even harder, and it takes years of study and practice to develop good cooking skills. Dissatisfaction with the level of chemical and scientific knowledge in cooking has led molecular gastronomists to study and push these transformations to new levels, creating food with forms and tastes previously inconceivable.

Our third digital gastronomy concept brings the art of transformation to the digital age by equipping users with the digital tools necessary to control the position, scale, duration and repeatability of food transformations in their own kitchens.

Transformation is a common term in digital processing and can encompass a wide array of data manipulations. Digital transformations offer advantages over their analogue counterparts: They can be highly localized; they can be undone innumerable times without detriment to the original data; and this data independence allows transformations to be easily replicated with consistent results, providing a powerful tool for designers to quickly experiment and test new ideas.

In cooking, transformation can be achieved through a digital machine: The Robotic Chef, in which algorithms respond to the individual properties of the food being cooked by intensifying or attenuating local transformations (Color Plate C No. 1). For instance, a laser beam can be used to burn the surface of a steak with an appealing visual pattern while also adjusting the power, speed and resolution of the beam according to the local amount of fat or meat thickness. Digital transformations can provide a source for new flavors and design patterns that would have been completely impossible to create through traditional analog and hand-controlled cooking methods.

The Robotic Chef is a mechanical arm designed to manipulate a single solid object, such as a steak, fish or fruit. It allows for two types of transformations: localized and precise manipulations performed with an array of tools located in the tool-head, and global transformations performed through the underlying bed and two six-degrees-of-freedom robotic arms. The tool-head holds an array of interchangeable manipulation devices, such as drill bits, spice injection syringes and a single lower-power laser diode, which can programmatically cut, burn, cook and spice the food held by the arms.

The underlying bed houses a heating plate to cook the food while the arm applies mechanical transformations, such as compressions, elongations and torsions, to control the location of the food underneath the tool-head. As with the above-described machines, all processes can be controlled from a computer through a user interface, allowing the use of preset manipulations or real-time control. These transformation processes allow users to perform highly localized food manipulations that are not achievable through traditional cooking methods.

Discussion

In this paper, we have so far described how tastes, forms and new food transformations can be created by applying digital technologies to cooking. In particular, we have described three different conceptual designs that imagine how far digital technologies may be incorporated into cooking. Obviously, for this conceptual investigation to be taken to another level, myriad technical and social challenges will have to be solved.

First, from a technical point of view, machine integration will require data quantification and the creation of reliable protocols for communication between different machine processes. Quantification will allow food and cooking processes to be digitally described and mathematically manipulated with incredible precision. For instance, a digital gastronomy refrigerator should yield precise knowledge about the food it contains, including the available quantity of an ingredient, its chemical composition, required storage conditions and how it affects taste receptors. This information could then be used to automatically order new ingredients, make informed decisions about food replacements or guide the workings of Cornucopia machines by forming the underlying data behind their communication protocols. Furthermore, before discussing the challenges of digitizing cooking, we should not forget that any new cooking machine needs to face pervasive constraints, such as the dimensions of meals it can support, the duration of cooking processes and how the food can be washed, cleaned and maintained.

Second, the capabilities described so far—mixing, modeling and transforming—could largely benefit from a single multipurpose machine that combines all three of our concept designs into one, allowing a user concomitantly to create new combinations, transform pre-existent (or newly invented) ingredients and model new 3D food forms. Leveraging the same flexibility we find in cooking, this would allow users to control the links and hierarchy between ingredients and the three food manipulation designs. Additionally, this machine should support a design workflow in which cooks could stop a process, taste the food, perhaps convert parts of it, accelerate a transformation, record the set of linkages that led to this outcome and ultimately have the capacity to experiment with new design ideas.

Machine integration, quantification and workflow raise important issues relevant to the mechanization of creative practices. Until a new design language, process and culture of production and consumption are fully developed, the digital fabrication of food could reinforce the social and cultural disconnect between food creators and food consumers, currently a significant problem in the fabrication of industrialized processed food. One need not look very far to see how the mass production and distribution of food has led to increased obesity and generalized health issues. This is a dangerous process—if not designed well, digital gastronomy can easily broaden the disconnection between people and food. Automation of cooking should be designed carefully by putting users' creativity and the control of the process at the center of the futuristic cooking experience. Users' profiles still need to be addressed. These would serve to help define how a single user versus a full family could benefit from such a technology. Also, the local instruments for a digital gastronomy presented here cannot be realized immediately and may even take a long time to integrate into society. A much larger scale of changes in food economics and food knowledge is needed for their success.

Networked Lives and Public Acceptance

The final outcome of food parameterization is the evolution of a networked food culture intrinsically connected to our networked information society. Distributing, purchasing, sharing and sampling recipes must become as easy and versatile as the consumption of digital music today, bringing about new economic models. A person 5,000 miles away could easily control our digital kitchen tools, forming an ecology of networked machines that can order new ingredients, prepare favorite dishes on demand and even collaborate with doctors to help all of us develop healthier eating habits. However, digital food machines cannot replace human touch and taste. In order to ensure that the technology will be implemented to the benefit of consumers and not corporations, more work needs to be done to guarantee an open system and to help users learn, control and define their dietetic needs, with unbiased access to information about ingredients, their sources and their freshness. Thus, introducing an open, web-based media interface to digital gastronomy is still one of the important challenges ahead. Beyond that, we are not willing to separate the process of cooking from the hands of the chef or the amateur cook—we envision that the machines herein described, or different ideas, will integrate with today's tools in a future kitchen that gives us, the users, more control over the process of making food, more information about what we eat and more possibilities of creating food without the requirement of being an expert chef.

We believe the contribution of this work derives from its vision of two narratives converging: that of the latest technology and that of the future of cooking. The illustrated machines and the user experience associated with them are not far fetched: They can be understood as a realistic vision and, as such, this vision encourages discussion and public interest. As in many cases in the history of technology, the path from vision to working technology is, in fact, shorter than we might think.

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