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Spotlight

OpenAG: A Globally Distributed Network of Food Computing

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In the 10,000 years of its history, advancements in agriculture have enabled three society-altering revolutions. From the domestication of plants and the resulting first human settlements in 8,000 BC, to the horse-and-plow and the rise of technology-based societies in 600 AD, and finally to the vertical integration of farming brought on by the mechanization, chemical fertilization, and biotechnology of today, agricultural revolution has always been a driving force behind humanity's societal progress.

The current industrialized food system feeds 7.2 billion people, of whom more than half live in cities and very few are involved in the production of their own food. //**Can you cite a reference here?**// The backbone of this system is comprised of large, centralized, chemically intensive single-crop farms. With natural resource scarcity, flattening yields, loss of biodiversity, changing climates, environmental degradation, and booming urban populations, our current food system is rapidly approaching its natural limit.

What will define the fourth agricultural revolution, and how will it impact and shape global societies? This is the central research question of the Open Agriculture (OpenAG) Initiative at the MIT Media Lab. As we //**at the MIT Media Lab? Or "As those of us involved in OpenAG…"? Or some such definition of "we" here.**// develop a greater understanding of the unintended ecological and nutritional consequences of industrialized agriculture, we envision an alternative distributed farming system based on new methods of communication, sensing, data collection, and automation that will enable network-effect advantages in the next generation of food production. We believe that food computing, open data platforms, and networked production communities will each play a pivotal role in the next agricultural revolution.

Food Computing

Donald Baker, a Distinguished Fellow in the American Society of Agronomy and the American Association for the Advancement of Science, suggests the following:

> *The third revolution may run its course or it may receive a boost from biotechnology. But with or without the application of a new technology, a fourth method of yield measurement may be used in the near future. It is the ratio of yield to a critical factor other than land. As the critical factor in the past has gone from human effort, to the amount of seed sown, to the amount of land used, it may soon change, for example, to the nitrogen, the phosphorus, or the energy expended. Perhaps the best one would be an economic one, since it also requires a superior bookkeeping system. Thus, the next yield expression might become yield per dollar spent.* ***//Where is this quote from?//***

It is the premise of the OpenAG Initiative that the "superior bookkeeping system" Baker refers to could be realized through leveraging the networked and computational power of "food computing" in the fourth agricultural revolution.

The food computer, or FC, is a proposed term for a control environment **//controlled-environment? Or are you referring to an environment in which you're controlling the agricultural environment?//** agricultural technology platform composed of robotic control systems and actuated climate, energy, and plant sensing. Not unlike climate-controlled datacenters optimized for rows of servers, FCs are designed to optimize agricultural production by monitoring and actuating a desired climate inside of a growing chamber. Climate variables such as carbon dioxide, air temperature, photosynthetically active radiation levels, leaf surface humidity, dissolved oxygen, potential hydrogen, electrical conductivity, and root-zone temperature are among the many potential points of actuation within the control **//controlled? See earlier question.//** environment.

These points of actuation, coupled with the *plant machine interface* (PMI), are the drivers of plant-based morphologic and physiologic expressions. For example, FCs can program biotic and abiotic stresses, such as an induced drought, to create desired plant-based expressions of color, texture, taste, and nutrient density. Operational energy, water, and mineral consumption are monitored (and adjusted) through electrical meters, flow sensors, and controllable chemical dosers throughout the growth period. When a plant is harvested from the FC, a digital plant recipe is created based on the corresponding data.

Digital plant recipes are composed of layered data that includes operational consumption data, plant morphology and physiology data, and a series of climate set points. Such points read like machine code and include a time stamp, an environmental control code, and a value associated with that environmental control. For example, a single climate set point reading of "00:00:00 SAHU 60" would set the air humidity to 60 percent at time 00:00:00 **//want to use a real time here for the example? "22:30:00" and "…at 10:30 p.m."?//**. All of these layers of data are compiled to form a repeatable digital plant recipe with known inputs and outputs. With iterative experimentation, we could hypothetically map the entire phenome of a selected plant and correlate certain phenotypic traits with specific environmental stimuli.

The *human plant interface* (HPI), also known as the user experience and user interface, is a software layer that allows a human operator to monitor sensors and actuator systems, browse and predict inventory and load, and override or create derivative digital plant recipes. The HPI abstracts the operator from the mechatronics and reduces the biological or engineering expertise required to operate the system.

There are currently three scales of FCs being developed throughout the world. The personal FC is a product-scale (2–10 sq. ft.) FC designed for an at-home user, hobbyist, or student (see Figure 1). The boutique production FC is a shipping-container scale (200–500 sq. ft.) FC designed for owner/operators or franchisees to sell small amounts of high-value produce into local markets, restaurants, or cafeterias (see Figure 2). The factory FC is a light industrial scale (+10,000 sq. ft.) FC designed to operate in urban or peri-urban environments and distribute fresh produce into a regional supply chain or produce a large quantity of a very high-value crop (see Figure 3).

Figure 1. A personal food computer. This FC is designed for an at-home user, hobbyist, or student.

Figure 2. The boutique production FC is designed for owner/operators or franchisees to sell

small amounts of high-value produce into local markets, restaurants, or cafeterias.

Figure 3. The factory FC is designed to operate in urban or peri-urban environments and distribute fresh produce into a regional supply chain or produce a large quantity of a very high-value crop.

Currently, these nascent systems are being developed as unique, closed, and proprietary systems that are non-compatible with FCs of the same scale or across scales. Knowledge is being developed locally on closed platforms, and questions of functionality, scalability, economic viability, safety, and environmental sustainability remain unanswered as a result.

Open Platforms and Data

At the MIT Media Lab, //**again, please define "we" here.**// we imagine a very different future, where open and compatible technology platforms underlie distributed scales of FCs operating on a network using digital plant recipes and //**the?**// climate as the scaling factor. Conventional agricultural data has been difficult to export and replicate, because it is dependent on the regional climate, local resource availability, and the time of year it was created. FCs operate autonomously of local climate. Therefore, an agricultural product created in one FC can easily be exported as a digital plant recipe and recreated, almost identically, in another compatible FC anywhere in the world.

This cross-platform compatibility would create the framework for rapid scalability of valuable discoveries. For example, innovations made at the product scale could be quickly tested and verified across a network of compatible FCs and then deployed at the shipping-container or light industrial scales. FCs, then, could be imagined as networked cores of agricultural experimentation and production, capable of responding to local or global environmental, cultural, or market demands.

As the global network of FCs begins to create, iterate, and deploy digital plant recipes, we imagine those recipes hosted on a public forum, such as Wikipedia, and downloadable as an executable file. Similar to the Human Genome Project, we envision the Open Phenome Project to be a crowd-sourced cataloging of all the plants in the world and their phenotypic traits correlated with the causal environmental variable. Over time, recipes will be optimized to decrease water, energy, and mineral use, while increasing nutrient density, taste, and other desirable characteristics. This database of functional plant phenomics will be the basis for scientific discovery, interdisciplinary collaboration, and new methods of efficient and distributed food production.

Food Net

//**Please update as needed.**// NOTE: Elaborate here on Communities, democratization of food production, empowering New farmers, Better farmers, contribute and share knowledge of food production, Continuous and accelerated improvement of food production, Socializing food production through recipes (forums, chats).

Open communities of food innovators, drawn together by collaborative and readily accessible technology platforms, will form the foundation of the next agricultural revolution. These communities will yield a diversity of thought and solution and will nurture new connections between people and their food. The more ubiquitous the tools and knowledge of production systems become, the more informed, innovative, and empowered the average person can be in contributing to the global future of food. The accessibility of data, hardware, software, and, most importantly, the accessibility of food and nutrition for the projected 9 billion people of 2050, hinges on fostering a creative forum of thinkers and doers on collaborative platforms.

//**Please provide a high-res photo.**//

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//Digital Library abstract and keywords—feel free to revise//

With natural resource scarcity, flattening yields, loss of biodiversity, changing climates, environmental degradation and booming urban populations, the current food system is rapidly approaching its natural limit. What will define the next agricultural revolution, and how will it impact and shape global societies? This is the central research question of the Open Agriculture (OpenAG) Initiative at the MIT Media Lab. The goal is an alternative distributed farming system based on new methods of communication, sensing, data collection, and automation that will enable network effect advantages in the next generation of food production. This department is part of a special issue on pervasive food.

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