Object-Oriented Publics

Tom Jenkins[1], Christopher A. Le Dantec[1], Carl DiSalvo[1], Thomas Lodato[2] and Mariam Asad[1]

[1]Digital Media Program
School of Literature, Media, and Communication
Georgia Institute of Technology
Atlanta, GA, USA

[2]Center for Urban Innovation
School of Public Policy
Georgia Institute of Technology
Atlanta, GA, USA

tom.jenkins, ledantec, cdisalvo, thomas.lodato, missasad@gatech.edu

ABSTRACT

Social computing—or computing in a social context—has largely concerned itself with understanding social interaction among and between people. This paper asserts that ignoring material components—including computing itself—as social actors is a mistake. Computing has its own agenda and agencies, and including it as a member of the social milieu provides a means of producing design objects that attend to how technology use can extend beyond merely amplifying or augmenting human actions. In this paper, we offer examples of projects that utilize the capacity of *object-oriented publics* to both analyze the conditions and consequences around existing publics and engage with matters of concern inherent to emerging publics. Considering how computing as an actor contributes to the construction of publics provides insight into the design of computational systems that address issues. We end by introducing the idea of the *object ecology* as a way to coordinate design approaches to computational publics.

Author Keywords

Design Research, Computational Agency, Social Computing, Publics, Object Ecology

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INTRODUCTION

Since the turn of the 21st century, publics have gained traction as a productive framing concept for design. The idea of publics as distinctive forms of social organization draw on the work of John Dewey [22], taking as a base assumption that there is not a singular all-inclusive public, but rather a multiplicity of publics. Key to publics, is that they are issue-oriented: a public is directed to the conditions and consequences of a particular condition—or set of inter-related conditions—in order to attend to their consequences [4].

In the 2005 exhibition and accompanying book, *Making Things Public: Atmospheres of Democracy* Bruno Latour reinvigorated the discussion of publics [69]. For Latour, publics are a way to understand how society deals with controversies and dilemmas, and as such, provide a useful bridge to design—issues are not expressed in the abstract, but are encountered through objects. Latour's call for an object-oriented politics, in which issues take place through things, reframed discussions about the politics of artifacts that were occurring at the intersection of design and science and technology studies. Arising from this disciplinary crossroads, there has been a spate of work across design studies [23,52], human-computer interaction and computer-supported cooperative work [2,3,7], participatory design [7,8,27], and science and technology studies [18,56,57] that examine the role of design in articulating issues and constructing publics.

Usually, the central concern when discussing publics is the organization of people. Publics certainly contain people, but that is not all they contain. Publics are, in fact, organizations of humans and nonhumans: animals, plants, atmospheres, buildings, buses, and so on. What is of particular interest to us is the role of computing as a nonhuman actor in publics. The designation "computing," for the purpose of this paper, collapses software, hardware, applications, and networking into a single term; our concern here is to consider broadly the category of computing artifacts and the ways in which they circulate socially and participate in publics.

The critical shift we are proposing is that by extending our understanding of computing beyond that of merely amplifying or augmenting human actions, we gain a new perspective from which to understand and interpret the role and impact of computing in social and cultural terms. We also gain new design opportunities to manifest alternative and speculative visions of future publics.

This maneuver occurs at the intersection of several strains of scholarship within the expansive tent of human-computer interaction. There are clear roots in research through design exemplified by such systems as Drift Table, Plane Tracker, or Prayer Companion [13,30,31]. Each of these examples point toward the ways in which the computational artifacts

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are in discourse with human actors—rather than simply augmentations of human actors. Furthermore, these projects and other like them and embody a distinct practice of critical design in computing [62]. Likewise, recent turns in computer-supported cooperative work toward sociomaterial design seek to "preserve essential sociomaterial practices in new design interventions" [9], thereby embracing the inseparability of object and social context by recognizing that artifacts participate in, rather than simply inhabit, those social contexts. Even returning to distributed cognition [36,37], we can see the trajectory that externalized cognitive tools are not just repositories of some prefigured human cognition, but are discrete actors with agency engaged discursively with their social context.

COMPUTING AS ACTOR IN PUBLICS

When we say that computing exists as an actor in publics, what we mean is that computing has a character and position of its own, and is an origin of influence and consequence that extends beyond that of either the designer or the user. This is *not* to say that computing does not augment and amplify publics—it does. But computing does something else too: it participates in novel ways in the constitution of publics.

By attending to the ways in which computing acts within publics, we arrive at a more nuanced, descriptive account of its role in society. Our goal is to provide design researchers with an additional perspective on how publics form and can be formed by shifting how we think of social computing where the sociality is not *enacted through* computational tools, but is *composed of* computation.

THE MANY FACES OF HYBRID AGENCY

Notions of agency that extend beyond humans are not new to the humanities, social sciences, or design, but they have gained renewed appreciation and attention in recent years [38,44]. This is broadly part of a nonhuman turn, which draws animals, plants, and other living entities into the endeavor of social and cultural analysis. Even beyond living entities, some social scientists and theorists are looking to understand the role of artifacts themselves and how artifacts and the materials that comprise them might exhibit various kinds of agencies [12,32].

Material Agency

Of the many humanities scholars that might be characterized as part of a "new materialism," Jane Bennett provides an important connection between notions of material agency and political theory [6]. For Bennett, one of the shortcomings of political theory is that it has not attended to the role of objects in the doing and experience of politics. This is not meant as a slight against human agency, but instead an opening of political theory to take into account how all manner of objects should be included in our understanding and analysis of politics.

Material agency provides a way to understand the effects of human and nonhuman collectives as an ecological whole where the effects arise only as a result of the distributed nature of a collective agency—spread among humans, tools, environments, and settings [5]. Much in the way distributed cognition allowed cognition to escape the confines of the skull [36], material agency opens the field of analysis for understanding social effects as the result of hybrid human/nonhuman collectives.

While this perspective on material agency is important to design research, it does not generally engage directly with design itself, neither in regards to the particulars of designed objects, nor in the processes and practices of design. For instance, a particular object might be examined in a general sense as a member of a collective, but the specific qualities of the design itself, in terms of form, construction, and affordances, are overlooked. These approaches also tend to lack a close reading of technology: a given technological system may be called out, as with Bennett's power grid, but the working particulars of the power grid is black-boxed. Some exceptions are found in sub-fields such as software studies or platform studies [59].

Actor-Network Theory

Following on from material agency, Actor-Network Theory (ANT) was developed in the field of Science and Technology Studies through the work of multiple scholars, including (but not limited to) Bruno Latour, John Law, and Michel Callon [47,50]. Despite its name, ANT is less a theory or method than it is a perspective. What was radical about this perspective was that it granted analytic symmetry between human and nonhumans. In addition, where theories of material agency often take nonhumans as black boxes, ANT worked to peer into the particulars of human and nonhuman networks to examine the specific ways technology acted within these networks. One of the central claims of ANT is that to understand a given technology, one must identify and follow the capacities of multiple actors, including but not limited to humans. One implication of this symmetry is that one can speak of the agency of nonhumans, ranging from scallops to doorknobs to speed bumps to algorithms. Rather than considering agency a material quality *per se*, within ANT it is less that any given artifact has agency, but rather that agency is an effect of the configuration of a network in which capacities, responsibilities, and authorities are distributed—delegated—among the variety of human actors and actants (nonhuman actors) that comprise the network [47].

Design research and ANT have crossed before, and continue to cross at many points. These intersections produce exciting exchanges between fields and lead toward new hybrid theories, methods, and perspectives in both design research and science and technology studies. Latour's work in particular has been influential to many designers [7,8,27]; of late, Latour himself has spoken directly about design [46]. There is also an emerging cohort of STS schol-

ars examining the practices and products of design, engaging the field of design research directly. These scholars include Albena Yaneva's research on architecture [73], Noortje Marres' research on material participation and publics [57], Mike Michael's research on speculative design [58], and Alex Wilkie's research on user experience [70].

ANT offers a connection between design and the social sciences that attends to the practices and products of design. Both share a commitment to the "object," or product, as having a capacity for action. Whereas other theories of agency privilege human action—in some cases exclusively—both ANT and design recognize the necessary role of the object in any and every constitution of society. However, while ANT does offer a bridge between the social sciences and design, there are limitations as well. In particular, ANT is useful for analyzing networks that already exist. Unfortunately, it is not a perspective that is well equipped for conceptualizing and generating networks (or products, or services) that do not yet exist. This mismatch for speculating about possible futures limits the utility of ANT for design [52].

Design *Things*

Growing out of ANT, the notion of *things* has begun to take hold within participatory design, particularly around renewed interest in engaging with the political effects and consequences of designed objects and systems [7]. Within design, scholars have advanced the notion of *things*, focusing on the way in which *things* articulate relations between humans and nonhumans [7,8,27]. Even amid the shift from the vernacular thing as a material object, something we would comfortably describe as a product of design, Binder and Ehn point out that the sociomaterial *thing* is also the product of design, and is an attempt to give design a language for imagining and generating networks of effects that include humans and nonhumans [7]. Furthermore, they contend that *things* should explicitly be the aim of design: "the outcome of the design process is a thing that modifies the space where people live: besides and beyond its functions (living for houses, hosting artworks for museums, sitting for chairs, etc.), the designed *thing* aims to change the experience of its users; it is rich in aesthetical and cultural values, opening new ways of thinking and behaving" [7].

This exposition of *thing* and its relation to design grows out of a concern with architectural design but applies broadly to similar kinds of effects and reconfigurations that arise out of actor-networks, whether tied to architectural design, engineering design, or those embodied in interactive technologies. Irrespective of field, the point of departure for analytic and generative engagement is the set of relations within the network of humans and nonhumans and the ways in which those relations exist in a constant state of flux. Here the issues at hand and the attachments to those issues arise from, and give rise to, the *things* themselves. In doing so, *things* are not merely augmenters of human action and agency, but are peers within a complex network of actors from which that agency arises and is enacted.

OBJECT-ORIENTED PUBLICS

Integrating a perspective that attributes agency to the full collective of humans and nonhumans into the notion of publics creates new theoretical opportunities in computing research. At its foundation, this shift in perspective enables a move from thinking about computing as augmentation, a technical appendage to human-centered concerns, and allows us to examine how technical artifacts and systems participate in the constitution and propagation of publics. The theoretical move from computing-as-augmentation to computing-as-actor traces and extends the intellectual and social agendas of contemporary computing research. While previous turns in computing examined the social construction of meaning *around* computing and the ways in which computing created, mediated, and amplified the sites and conditions of that social construction [1,43,66], we are moving into an era where we need to consider the social construction of meaning and action *with* computing.

This new theoretical position opens up both new *analytic* territories as we examine computing artifacts and systems with respect to the ways in which people and computing become conjoined as publics, as well as *generative* territories that take as their departure point the agency of the artifacts being designed. The case studies below help us examine this new landscape of object-oriented publics, highlighting the considerations for an understanding of social computing built around the shared, distributed, and concurrent agency of *things* in the world.

Examples of Object-Oriented Publics

Drawing more specifically on the theoretical perspectives above, we can return to familiar research sites to illustrate the features of publics that arise through the ways in which computing configures human participation and the ways in which computing's agency is made material. These examples constitute a broad category of social action and activity where the present practices require not just embracing the entanglement of social and material elements [9], but where the collective agency and capacity to act necessarily arises out of the shared participation of human and non-human actors.

At first blush, such an analysis may simply ring as a familiar application of ANT to the concept of publics. Where we differ, however, is in attending to the complementary ways in which specific computational capabilities enable new capacities for action and for new publics to convene; and where the particular arrangements of publics enable new computational possibilities to emerge. Our argument here is not just that humans and computing act within a network together, but that we fundamentally encounter social computing as an agentic discourse between people and computation. We contend that *all* computing is social computing, and that such an analysis provides cracks from which to

peer into the black box and understand the shared agency in both small-scale, intimate interactions with computing as well as in the large-scale systems that organize and mobilize society.

Cycle Atlanta

Since 2012, we have been involved in a project that has tapped into trends in data-driven governance and crowdsourced models of public participation. Through a smartphone app released in Atlanta, citizens can record their bike rides, uploading route data, ride purpose, and rider demographic data. These data are used by city transportation planners as an empirical basis upon which to make decisions about where and what kind of cycling infrastructure might be necessary to create a robust and diverse urban transportation system.

Beyond the pragmatic, instrumental goal of generating data about where current cyclists were riding, the project provided avenues for public input into the planning process, broadening public input so as to make infrastructure plans both better and better-accepted when implemented. The deployment of the smartphone app channeled two streams of contemporary optimism in how digital technologies can transform urban and public life: the first drew on the vision of smart city projects where sensor networks [60,67], instrumented infrastructure [28,61] and participatory sensing [24,63] are interwoven to improve operational efficiency in city services and planning [61]. The second drew upon moves in digital democracy to decouple public participation in policy development and governance from the physical and temporal constraints of public hearings and other modes of face-to-face interaction between authorities and citizens [34].

The project integrated these two perspectives by linking instrumented data collection with democratic participation: the phones of citizens were enlisted as sensors to generate new streams of data for urban planners and the act of sensing bike routes was a form of advocacy for new infrastructure, one that was decoupled from the public meetings and design charrettes where such advocacy normally took place. However, more than simply augmenting how cyclists participated in an urban planning process, the mere existence of the app enacted a set of political realities with respect to the city. The app enabled the city to position itself as a progressive, data-driven, and technology-embracing place. These realities carried rhetorical weight for elected officials and citizens alike but also introduced the app itself as a material participant in the democratic process.

More than simply amplifying cyclists' public participation in the creation of policy and the design of physical infrastructure, the app acted as a member of a public and had unique relations to different stakeholders involved. Some of these relations came through use, where the communities who used the app provided accounts of geography and mobility that reified existing socio-economic boundaries in an empirical and authoritative way [16]. Others came through non-use where issues of community identity, gentrification, race, and class became viewed through the lens of data-based participation [15]. In some instances, the app participated just by means of existing: in planning meetings, we observed planners and engineers refer to data that might be collected by the app in the future as justification for planning decisions. Here, human participation was inferred—positioned as augmentation to the technology—and the app, as an element of the near-future smart city, enabled new political and policy claims to be made along the contours of who participated with the app and who did not.

Like other infrastructure sensing apps—for example, Street Bump, deployed in Boston to detect pavement quality issues—our app enlisted computing as an active participant in sensing and advocating for public resources. As one of the Street Bump developers explained, these apps create "a new kind of volunteerism," where it was not the citizens themselves, but instead "the devices that are in [citizens'] pocket" who are doing the volunteering [14]. Taking this quip seriously means treating the technology as an actor in a network of concerns and motivations—it is a participant in a social and political exchange, and not simply a medium for such an exchange.

A more familiar analysis of the role of the smartphone app might trace claims that the collection of data amplified the cycling community's ability to have input into the planning process by decoupling it from the limited venues of in-person advocacy. It would also argue that the collected data augmented planners' ability to make rational decisions based on novel sources of ground-truth data. Such an analysis presumes that the agency of collecting data and making use of data rests with human actors, and discounts the role of computing as simply aiding that human agency.

Instead, we would argue that the app and the data both participate as members of a cycling public. Through this participation, issues arise with respect to equity in participation, veracity of representation, and accountability and transparency of civic institutions [15,16]. These issues are all bound up in the human and nonhuman composition of the public, resulting in a *thing*: the computational agent, comprising sensing capabilities and data production that enable an alternate means of contesting urban planning. Around this *thing*, a public emerges where humans and nonhumans engage in negotiating the development of physical infrastructure. This public is both shaped by the participation of the app and the collective agency is materialized through maps, data visualizations, and planning analyses that are built upon the recorded route data produced by the app.

By itself, the app is also only part of the computational agent that participates in this public. The way data are stored, operated on, and analyzed is also part of that computational agency, not just informing the human actors with respect to setting public policy and designing bicycle facili-

ties in a dense urban center, but changing the kinds of questions they ask and the kinds of answers they receive. In short, the app became a new kind of implicated actor in the process, one that in many ways advocated for its own perspective, its own validation and its own self interest. By shifting policy discussion to terms that required the presence of certain kinds of data, data produced by the app, the basis for democratic decision making likewise required the app be a participant, a member of a privileged constituency [16]. Where the basis of digital democracy is "to practice democracy without the limits of time, space and other physical conditions using [computing] as an addition [to], not a replacement for traditional 'analogue' political practices" [34], the facilities that enable that decoupling are not inert. Rather, they are a *thing* that exerts force through material agency.

Issue-oriented Hackathons

Shifting from a context where a new computational agent gave rise to a new public, we now turn to examine a category of publics that give rise to new computational agents: the hackathon. Originally organized within software companies to address labor-intensive development tasks, hackathons have emerged as a widespread activity in recent years. In general, hackathons focus on the development of technical—often digital—prototypes of services and systems. Attendees are presented with tasks (referred to as challenges) and groups form to design and build prototypes that address the topic area of these challenges.

While many of these events are organized around a technical topic, such as smartphones or mapping software, a segment of these events are what we call *issue-oriented hackathons*. These hackathons focus on social topics, such as sustainability, ecological change, civic responsibility, or international relations. Unlike technically-oriented hackathons, issue-oriented hackathons have aspirations of addressing these social issues through technical means.

An example of an issue-oriented hackathon can be found in the Food Data Hack, a one-day hackathon focused on the local food system of Atlanta. The event invited farmers, food advocates, entrepreneurs, service designers, web developers, and community representatives to envision and plan technical prototypes that addressed issues related to land use and food access. While the Food Data Hack emphasized design over development, the event asked participants to consider the role of computational artifacts—smartphones, web servers, and publicly accessible databases—in these issues. Structured around these particular artifacts and this topic, participants used computation and computational systems as a means to express the underlying concerns and dilemmas of land use and food access. For example, one group proposed mapping the available resources in an underserved community. This proposal framed creating, articulating, and storing user-generated data as a means to collectively overcome the lack of infrastructural resources in that community, both providing resources for residents and articulating the community's needs to those outside. As such, digital mapping and the digital map both came to embody the need of the community to be heard as well as legitimizing their concerns materially. If in fact the map had been fully executed, it would have functioned in a manner similar to the cycling app: as a computational thing that gave form to an issue and produced data which could be used as the basis for negotiating actions to be taken on that issue.

Particularly striking about issue-oriented hackathons is the way these events deal with computation as both a means and an end to think through social issues. One might choose to dismiss issue-oriented hackathons because they form around an idealistic—and maybe foolish—premise: that building technological solutions to longstanding social issues is possible over the course of a weekend. Dismissing these events, however, misses a profound insight. These events assume that computing and computation has a role in social issues and are driven by an intuitive alignment of technology as a *thing* and computation as a participant in an object-oriented public constructed to contend with the social issue at hand. Issue-oriented hackathons are based upon an implicit belief that computational artifacts can be designed and deployed as actors to effect change in contexts where human action alone has not succeeded in doing so. As such, issue-oriented hackathons can be viewed as a site to explore computation as a means to articulate both existing as well as new social arrangements.

Issue-oriented hackathons and the Cycle Atlanta project both offer an example of an activity that prefigures the role of computation within these issues, namely, by suggesting computation has a role at all. Furthermore, the role that both suggest points toward participation with collections of computing artifacts: from apps and websites to databases, servers, and libraries of code. This in turn outlines multivalenced, relational orbits among human actors, between human and computational actors, and among computational actors. Some of these valences are better understood, where the social sciences and human-computer interaction have a substantive history mapping bonds like these [25,47,51], but others are less well known—in particular the sociality of computational agents—and require consideration on their own.

Object Oriented Publics as a Design Tool

Object-oriented publics provide a starting point to consider the specific and concrete ways computing material might participate more actively within social computing. More than providing a novel analytic perspective, they enable us to create alternate possibilities for participating in computing, to move beyond computing as a mere augmentation to computing as an agent in its own right. Again, we focus on the notion that all computing is social computing, and that sociality is not just enabled or mediated by computing, but acts *with* computing as a co-participant.

Activist Technology Workshops

We have been working with housing and social justice organizations to understand the sociomaterial work practices that govern different forms of advocacy and activism. Through three years of ethnographic fieldwork and a series of co-design workshops, our investigations have documented the temporal, social, and political constraints in which activism operates; the values of social equality and institutional accountability that guide activists' actions; and the antagonistic tactics deployed to realize their goals [2]. Many of the constraints under which activist organizations operate mirror those of social service non-profits [19,68]; however, while non-profits and non-governmental organizations might try to provide services or influence policy decisions through established channels of influence and power, activists work outside of those channels, relying instead on direct action to bring about social or political change.

To a certain extent, activists' use of computing can be seen as a case study of non-profits pushed to the extreme: resources are more constrained, there is a heavier reliance on volunteers, and moment-to-moment work is contingent and irregular. However, by reframing activist technology use as a kind of information work, their particular use—and often, appropriation—of computing reveals how computing systems and artifacts become crucial co-participants in their political action.

As a result, materiality becomes crucial to activist work, particularly when involving computing. While protests or marches are often seen as spontaneous or unplanned, they are usually quickly organized as a response to an unforeseen development or event. As an example, housing justice activists may need to respond to a resident being evicted without notice. It is in these moments of crisis that computing's materiality is made prominent: the organization needs to respond by marshaling resources through different channels; they need to organize in-person support for the evicted person or family; and they need to personalize the event to build empathy and draw public support to the more general issue of housing justice [2,3].

As part of that information work, an array of computing systems and artifacts become enlisted as participants working under the mandate of the activist organization. For example, social media channels position local action within larger regional or national issues to connect the organization's work to other, related groups and concerns. Social media is also used to broadcast operational information meant to guide and inform local action, as well as to circulate information more widely as evidence of contested social conditions. Likewise, captioned images called "macros" (typically used to propagate humorous internet memes) are created to generate widespread awareness and recruit further support either through in-person action or through visibility online [2]. These computational objects and artifacts are *things* that arise out of the particular circumstances of protest and activism and disperse into the world to marshal support and mediate communication.

Looking beyond the ways in which activists participate with existing computational *things,* we also explored the creation of new computational resources that would advance the political and social aims of the organizations [3]. These workshops revealed a cast of speculative computational actors that could work proactively within the organization—including capabilities for sending messages, monitoring authorities, and sustaining individual and organizational ties. Like the turn to computation in digital democracy, recruiting new computational actors through speculative design created new participants in the activist network.

However, unlike the recruitment of social media platforms in regular operations, the objects that arose out of the design workshops accomplished different goals for the activists. Where the *things* that arose from social media—the Twitter feeds and image macros—worked to create wider shared attachments to the social issue of housing justice, the *things* that resulted from the design workshops served to create a critical reflection on both the conditions of protest and the ways in which those conditions are altered with computing. Like the issue-oriented hackathons described above, the design workshops shifted the frame of who and what could meaningfully participate in acts of peaceful protest by expanding the material of such political acts.

Across these two categories of computational things—the existing social media platforms and visual communication genres, and the speculative creations resulting from a critical making workshop—the individual and organizational work was not simply mediated by these artifacts, but altered and constituted by the collective network of human and computation actors doing the work. Put another way, the work practices of the activist organizations required the participation of an ecology of computing: mobile computing devices, data plans, shared documents, cloud services, and access to social media. It was only through the joint participation of these computing artifacts that the collective agency of the organization was able to activate social networks and constitute an ad hoc public to take action in response to an acute (if otherwise systematically entrenched) event.

Tiny Tinkering Platforms

Our final case study concerns the Internet of Things (IoT) as an assemblage of people, technology companies, concerns around privacy, corporatism, upgradeability, cost, material objects, utopianism, and more [32]. These actors all play a part of the Internet of Things in practice, and understanding what these are and how they operate at a low level is important to understand what kinds of values are being built into the rhetoric driving technical practice—and what might be left out. Participating in the Internet of Things may begin with a person buying a thermostat or smart refrigerator, but it should also include a recognition

of how the thermostat and refrigerator are themselves participating, their computational assumptions reflecting choices made in their design and manufacture. Put differently, the IoT is an Internet of *Things*. It is an arrangement of material actants—nonhuman, computational agents—that participate actively in the daily life of the home; however, the modes and rhetoric of participation are usually black-boxed and inaccessible. Algorithmic assumptions about what might be done at a given time, the sensing standards that learn habits from the owner's everyday patterns, the seamless integration into larger systems extending outside of the home, all of these exert forces that are not obvious and often intentionally obfuscated to the end user.

To explore the *things* of the IoT, we designed and constructed a very simple prototyping platform—the "Tiny Tinkering Platform"—to explore building barely-smart materials in the home. These prototypes were aimed at subverting commercial IoT rhetoric [39]. In its place came an IoT that was emergent and contingent rather than centrally controlled; it put an emphasis on material, computational, and human collaboration rather than parameterization of the everyday world for reporting elsewhere. This platform could be used to construct small-scale, human-evaluated systems, as well as to build more complicated, communication-driven devices that still need humans for assessment. In these systems, the output stays *in situ*, and people around them draw conclusions for themselves. In this frame, end user gratification comes not from owning something new and remarkable to show off to the world, but in producing something unremarkable that feels important to an individual or small community. Possible applications might include when to water a particular plant, when hot coffee has reached the correct temperature, when the mail has been delivered, and so on. While these examples are toy problems, to be sure, they served as a useful environment in which to explore a computational ecosystem focused on reducing the complexity of engineering ubiquitous small-scale hardware. In these scenarios, the computational object serves as a rallying point, making possible new arrangements of things.

In prototyping new organizations of sociotechnical material, we have had to take a deep look at how people live and how they interact: what simple, measurable opportunities exist that could become a site for intervention or problem solving? To that end, one unforeseen outcome of developing a platform like this was enforcing a kind of algorithmic lifestyle on prospective users. The platform produced devices that comprised cheap, ubiquitous, computational material assemblages—materializing the experiences that everyday objects have, but only partially translating them into the language of the observer. Rather than emphasizing screen-based interactions with computer-controlled devices, giving directions or setting rules from a cellular phone or personal computer, our Internet of Things instrumented the everyday on its own terms, letting them become partners in ubiquitous meaning-making.

IMPLICATIONS OF PUBLICS BEYOND PEOPLE

In each of the preceding cases, we describe how computing plays an active role in the constitution of a public. This requires that we recognize and appreciate that a) publics are not solely made of people, and b) that to understand the formation and activities of publics, we must take into account the agency and material capacity of computation.

The Political Agencies of Computation

The discourse and debates on the politics of artifacts is long and messy [41,71,72]. As designed and constructed *things*, algorithms, platforms, networks, and other forms of computation are drawn into this discourse. However, there are important material differences between an algorithm or a platform and, say, the freeway bridges of Richard Moses that science studies scholar Langdon Winner famously labeled as racist [71]. The agencies of computational media tend to be more dynamic. Put bluntly, the algorithms and platforms of computational media act with a greater frequency of change than does the concrete of bridges or other aspects of the built environment. However, the legibility of these computational agencies is less than those of other material fixtures. We may see change or effect in computational media, but often the basis of that change is not understandable. For instance, Gillespie has explained how Twitter trending patterns have been incorrectly read as politically biased because of a misunderstanding of how the trending algorithm works [33]. While we may mistake some forms of computational media as political, we may also be unaware of other political algorithms at work—such as those used by the United States National Security Agency to profile and track "suspicious" behavior online. In the former case, the trending algorithm of Twitter may seem to be thwarting the formation of a public, but in fact it is not. In the latter case, the surveillance algorithms may be unseen or even unknown, but nonetheless should be considered as part of the public formed by the U.S. NSA to attend to the perceived issue of terrorism.

Recognizing the political agencies of algorithms, platforms, and data requires that we broaden the space of politics and expand what counts as political engagement and organizing. Most discussions of politics swirl around common civic institutions and mechanisms of government. For example, political engagement tends to mean working with political parties or governmental agencies or civic organizations, such as churches and various clubs. Broadly speaking, most political projects tend to be projects that contribute to the processes of such organizations. This covers a diversity of activities and outcomes, from neighborhood cleanup days that aim to improve and sustain a sense of community through shared pride, to get out the vote campaigns that strive to increase participation in the most basic component of a representative democracy. This work is imperative for the functioning of the state and the well-being of residents. But these ways of framing the space of politics, and of what counts as political engagement, are

insufficient to account for the agencies and effects of computation.

Consider, for instance, the data generated of the *Cycle Atlanta* project. These data cohere a public by providing a unifying organization to a range of human actors and their actions. The data collected are thus not only traces of individual actors, but also in the aggregate a bundling of those actors and a binding of them to an issue. The data and algorithmic analysis of those data do even more, though. They become constituents in the public, actors that need to be taken into account on their own terms, and recognized for their potential to effect change independently.

By accounting for the cycling app as an actor we arrive at a position from which we can examine both smart city and digital democracy initiatives. Similar applications exert their agency over the delivery of services, the development and maintenance of infrastructure, and the operations of government. The implicated technologies are not only servicing human goals and desires, but are exerting an influence over representation, governance, and accountability that extends beyond that of human use: the very presence of the app alters what *counts* as representation, governance, and accountability.

A similar example is also found in the *Activist Technologies* work. In that project, an activist public is mobilized through a series of networked hardware and software platforms. These platforms do more than just coordinate action; they also shape the possibilities for action due to a range of medium-specific capacities and affordances. The resulting agency is distinctive and possible only through the enrollment of computation into activist politics.

Considering computation as political actors is not the naïve claim that an algorithm or data exert authority over the person, nor is it an embrace of technological determinism. Rather, it is an acceptance of the capacities of computation into the figuring of a public. This presents two, entwined challenges. One is how to *understand* civics when the platform and the algorithm are considered as actors in the civic endeavor. The other is how to *do* civics when the platform and the algorithm are considered as actors in the civic endeavor.

The Creative Agencies of Computation

The second way we want to interpret the agencies and effects of computation is through the influence they exert on creative endeavors and the formation and support of publics oriented around modes of imaginative production. These agencies are not political agencies, but rather creative agencies. Making, inclusive of so-called maker culture as well as a broader collection of activities and movements is an increasingly important site for design research [40]. The activities of making can be closely aligned to a wealth of scholarship on material agency, particularly with regards to the agencies of materials in craft and arts [44,54,64]. Until recently, less attention was paid towards the material agencies of computation; however, attending to the material qualities of computation provides insight into how inventive publics form to address the issues and opportunities of imaginative making.

Recognizing the creative agencies of computation requires acknowledging how computation shapes the formation of publics around the processes and goals of invention. In his discussion of the agency of materials in the practice of ceramics, Malafouris notes that making pots is an endeavor that involves the negation and collaboration of many factors that extend beyond the potter herself and include the agencies of clay and the various tools of the potter [54]. In a similar way, we can see the activities of invention that come from various forms of computational tinkering as an interplay of agencies beyond the maker. The expressivity of the system is in large part determined by factors other than the human hand. For instance, in *Racing the Beam,* Montfort and Bogost provide a detailed examination of how the computational capacities (and particularly the limitations) of the Atari 2600, together with the capacities and qualities of cathode ray TVs produced the conditions of early gaming that set expectations for the experiences of what "playing a video game" was [59]. The ingenuity of early game designers was not merely in producing creative game mechanics or novel play arcs, but (like the potter) of negotiating between the various agencies of the multiple factors that made video game play possible.

Making, designing, and creating are not always solitary affairs. Communities develop around these practices, and those communities can be considered publics, oriented toward the issues of invention [65]. These publics vary according to the size and scale of their inventive endeavors. The *Tiny Tinkering Platform* is an example of how attending to the agencies of a computational platform can be generative of new publics and experiences of doing computation. The design of the platform—from the level of the microcontroller—was specifically intended to foster a particular orientation towards the issues of making with computation. By purposefully restricting the capacities for expression, the platform was intended to bring into being a public with a distinctive aesthetic approach, one committed to and organized around a kind of material minimalism, quite similar in fact to that of the early Atari.

As a speculative gesture, the *Tiny Tinkering Platform* becomes part of a public concerned with how activities of making are being shaped in relation to dominant discourses of innovation. In a manner similar to *Cycle Atlanta*, the design of the speculative platform intends to both cohere a public through its agencies as well as become an actor in that public, contributing to providing an alternative.

Issue-Oriented Hackathons provide yet another perspective on the creative agencies of computation. It is not simply the human resources that shape the creative output of these events. In these events, the availability of computational resources also shape the possibilities for invention. This is

particularly true when regarding data as a material for expressivity. What data is available will exert a strong force upon what kinds of secondary computational expressions get created (for instance visualizations, or maps, or apps). One way to perceive the extent of this agency is through the *absence* of computation resources—in a hackathon where there is no geo-located data, it becomes difficult to imagine, much less produce, a map. Any public that forms at a hackathon, then, is in part determined by the computational resources at that hackathon. The resources themselves become actors in the public by shaping what it can or cannot attend to.

Considering computation as an actor that shapes creativity does not lessen human creativity. It simply extends a line of thinking with regard to how materials shape expression. Moreover, with regard to publics oriented around forms and modes of imaginative making, these agencies extend beyond shaping the expression of the object or system to shaping the community that comes together to explore the inventive opportunities of computation. In these publics, computation is not just the subject of inquiry, it also acts to structure expression both by its capacities when it is present, and by what it thwarts in its absence.

From Networks and Publics to Ecologies

As mentioned earlier, one shortcoming of ANT as it applies to design is that it does not easily support generative design practices. ANT is useful for post-hoc analysis of networks that already exist, but it is not a perspective that is useful for conceptualizing and generating new networks or the products and services that might operate as actants within them. This mismatch for speculating about possible futures limits the utility of ANT for design.

Another frame is needed. One that is *both* analytic and generative, and that offers notions of interconnectedness distributed across multi-faceted agencies.

We propose that one option moving forward is to shift the frame from networks and publics toward a more ecological approach. Ecological thinking requires a broad perspective that foregrounds various connections between objects and systems. By revealing this multiplicity of obligations in an explicit way, and approaching publics as containing computational agency, we expose objects in the world as always having been members of multiple networks, involving themselves in social arrangements in both subtle and dramatic ways. This simultaneous involvement in various networks—information, electronic, legal, cultural, material, and more—means that objects and designed systems cannot and should not be treated as discrete instances. Instead, they must be considered as component members of an assemblage of actants and relations—what we consider an *Object Ecology*.

In HCI, design is being used to propose and articulate possible or even preferable futures [26]. Design assumes the role of speculator, investing rhetoric into objects in order to create artifacts that take a stand, that play an active part in stretching the boundaries of the possible while asserting particular ideological visions. Contemporary HCI design cannot and should not be concerned with a solitary object or interactions with that object alone. Instead, we must take into account how an object becomes contextualized within collectives of people, other objects, values, contexts, social configurations, and so on. We claim that design provides a means to create *things*—in both senses of the word—as giving form to devices, objects, and systems, of course; but also in creating assemblages that let members of an ecology participate and act among the world at large.

Broadly construed, ecological thinking is not new to HCI. Researchers have previously described *product ecologies*, *device ecologies*, and *artifact ecologies*. Each of these carve out different areas of focus, from how the design products come to be used and cared for in a product ecology or milieu [29,55]; to the personal ecosystem of devices that mediate experience and exposure to other personal technological ecosystems [42]; to the way networks of artifacts shape and influence conceptions and potentials for use [10,11]. Each of these ecological perspectives, however, place the focus on the interpretive power of the human user and do not account for any agentic property of the object as such. By considering ecologies instead as containing multiple object oriented publics, each coalescing and offering sites for contestation around various co-imbricated issues, we can do design for publics that take broader social conditions into account.

Running parallel to the developments of different ecological frames within HCI, there has been a recognized need for more deeply engaging material perspectives [21]. As discussed above, scholars like Bogost [12], Latour [45,48,69], Bennett [5,6] and Harman [35,49] have taken a more bi-directional understanding of meaning construction through interaction. In taking the things that surround us as having an active role in shaping and understanding the world, we can move away from the idea HCI design as being primarily interested in creating *products* or *services*—terms that cast things as being primarily transactional—towards something more relational. Here, the scope of an object ecology offers a way to do design beyond an issues interaction with a community. The object ecology provides a theoretical perspective that emphasizes objects, publics, communities, and issues in themselves, for sure, but also the interplay between them.

This may be an alienating move, but one that we feel will pay dividends for design practice. Existing perspectives on materials are beginning to feel inadequate, especially as we consider computation as participating members of publics. This perspective is useful in two ways:

First, the object ecology forces a designer to consider a broader design space—one that might serve to help unpack or take into account complex interactions and interrelations.

From an ecological perspective, the *Tiny Tinkering Platform* provides an opportunity to investigate the interrelation of Internet access, materials, and everyday experience, while emphasizing particular values through design activity. By building a new hardware system that devises different types of connections to materiality, the project critically examines the role of objects in the everyday. It also strives to create a speculative ecosystem of capacities that reduce the complexity in improvising solutions for small-scale, ubiquitous problems.

Regarding *Speculative Activism*, this means that design efforts need to account for mobile computing devices, data plans, shared documents, cloud services, and access to social media not simply as multiple points for interaction, nor even as sites for sociomaterial-design [9], but as an object ecology with its own internal logics. These logics may be governed algorithmically, or materially; they may be legible, or more likely, are rendered opaque or invisible. As a site for productive design and intervention, however, an object ecology spurs speculative claims both about how a public might impact social or political conditions as well as how those new conditions might be maintained through that collection of imbricated agents.

The object ecology also becomes a useful way to consider how designed objects help mobilize a broader ecosystem as members of publics.

In contrast to the more speculative moves an object ecology enables above, projects like the crowdsourced data collection in the *Cycle Atlanta* case illustrate the ways in which the ecology of mobile apps, databases, modeling and analysis make diffuse publics acutely visible. The plural material and human agencies percolating through the cycling public support each other and widen political participation to include computational and human actors. Again, as a site for design and design research, such contexts provide large-scale laboratories for experimenting—speculating—on what a computational civics might look like and what kinds of actants it might regulate.

In the case of *Issue-Oriented Hackathons* the notion of the object ecology is particularly useful because it, at one and the same time, takes into account the material and experiential qualities of the event. In fact, in an object ecology, these are inseperable and they work together to construct the character of the event. The hackathon is itself an ecology of people, code, hopes and aspirations, APIs, pizza, and power cables that comes together with the issue to produce a particular set of relations for a set period of time in a specific configuration of space. An object ecology has us examine those relations and how they are structured to produce (or thwart) a cooperative endeavor, a working together of humans and nonhumans in the context of an issue. Unlike ANT or other perspectives that flatten ontologies, the object ecology appreciates how differences work together to produce different publics. Those different publics are as much as factor of the capabilities of machines as people.

Part of the goal of considering the built environment as an assembly of specific contextual things is to be responsive to the particulars of a particular context or situation. The object ecology takes the everyday built environment as an assemblage of *things*. The role of design in producing new design things from an ecological standpoint is to consider the interrelatedness of these things and to prototype novel, interesting and—more importantly—worthwhile social interactions between and among them.

CONCLUSION

In this paper we have explored how computation, broadly construed, contributes to the constitution of publics. We have also made the argument that computation should be considered an actor in these publics. That is, computation is active in shaping a public: a public is not simply the expression of human desires, fears, and values with regards to an issue, it also includes the capacities of objects and systems that are used to attend to an issue. While there are likely multiple kinds of computational agency, we called out two that were generalized from our cases: political and creative. Certainly, these are not the only agencies and effects of computation on the construction and working of publics.

The notion of an ecology, we propose, is qualitatively different from a network, assemblage, or even the broad claim of material agency. The notion of an ecology suggests a quality to the relations and engagements between the entities—human and nonhuman, living and not living—that compose it. An ecology is not simply interconnected; an ecology exists together. The question for us as designers then, is what do we want the character of that existing together to be? Arguably, the role of design in shaping this ecology should be to construct relations that support a pluralistic approach to *meaningful* and *worthwhile* interactions between these entities, without reducing them to merely the human perspective.

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