Algorithmic Governance in Smart Cities

The Conundrum and the Potential of Pervasive Computing Solutions

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Pervasive and mobile computing technologies can make our everyday living environments and our cities "smart", i.e., capable of reaching awareness of physical and social processes and of dynamically affecting them in a purposeful way [1]. This is already happening, e.g., in the form of digital traffic signs that suggest in real-time the best traffic directions or the availability of parking spots, and also in the form of location-based social networks that inform us about noteworthy events. Soon we expect that the pervasive diffusion of sensing, actuation, and computing will allow our urban environment to fully self-regulate in autonomy most of its processes, and to guide and support our everyday activities.

It is generally acknowledged that living in a smart environment makes us smarter by increasing our overall levels of awareness of ongoing urban activities [2]. Also, by supporting and facilitating our customary activities (e.g., driving, finding information, and goods), living in a smart environment can make life much more pleasant and less stressful, and also make the environment more sustainable.

However, the evolution of smart environments also carries potential risks for individuals and for society as a whole. In particular, if most of our everyday activities can be automated, we could be tempted to increasingly delegate the governance of such activities, and the governance of the whole city, to the algorithmic engines of the smart city infrastructure. Thus, rather than taking advantage of the augmented capabilities of perception and participation enabled by the technologies, we could end up losing critical attention, abandoning individual decision making for relying on collective computational governance of our activity, losing awareness of environmental and social processes, and ultimately lose power and become dumb [3].

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In this article we elaborate on the key concepts of algorithmic governance in smart cities, discussing its likely increasing role in the future. Without any intention of dramatizing or of embracing dystopian visions, we intend to outline some specific problems that could potentially occur in future smart cities, and eventually analyze some key directions to prevent or mitigate — also with the fundamental support of pervasive computing technologies — these potential problems and possibly turn them into advantages.

Smart Cities: From Citizen Support to Algorithmic Governance

Algorithmic governance, in general terms, concerns empowering software to take decisions and to autonomously — i.e., without human supervision — regulate some aspects of our everyday human activities or some aspect of the society, according to some algorithmically defined policies [4]–[6].

We are already subject to algorithmic governance in a variety of different aspects of our personal and social lives. Google search dictates what information we find on the Internet, as we typically accept the suggestions appearing on the first page. Facebook news feed algorithms dictates what are the relevant posts to show us, and given that young people rely on Facebook as the primary source of news, this implies that they have fully delegated to Facebook the activity of seeking and filtering information [7].

Moving from the individual to the societal sphere, examples of algorithmic governance can be found in trading, where most of decisions (and thus the oscillations of markets and our finances) now rely on complex agent-based decision making; or in the pricing strategies of airlines that rely on complex analysis of travel trends.

In the area or urban management, some early examples of algorithmic governance can be found in traffic management (e.g., traffic lights that adaptively their frequency depending on the sensed traffic flow), public transport (e.g., to adapt bus schedule and routes to meet the transport demand in real time), and energy management (e.g., to automatically tune energy pricing depending on the instantaneous balance between supply and demand).

Current examples of algorithmic governance for smart cities still rely on rather limited capabilities of sensing and actuating. However, the increasing spread of pervasive computing and Internet of things (IoT) technologies will soon make it possible to sense at incredible levels of detail every single event happening in every corner of a city, and to trigger flexible actions to affect the state of things via a variety of actuators, robots, and autonomous vehicles [1]. The assessed mid-term future for urban mobility is the one in which citizens and merchandise will be carried to any desired destination via myriads of self-driving vehicles, globally orchestrating their movements and routes with each other and with the urban street infrastructure. Similarly, the flow of pedestrians will be somehow steered (via digital signages or apps on wearable devices) and orchestrated so as to avoid dangerous situations [8].

Pushing the vision forward, we can imagine that the entire management of cities will be soon governed and actuated in an automatic, unsupervised way. For instance, this can include the management of waste collection (which also includes the possibility to make citizens individually accountable for what they produce as waste), decisions on new urbanization, and management of roads and other infrastructure (e.g., by automatically deciding which roads and traffic lights to replace depending on their actual state and available budget).

In general, living in a smart environment and being made part of its awareness can potentially make us smarter. That is, it can notably increase our perception and social capabilities [2], and our ability to understand situations and react to them. In addition, allowing our everyday urban lives to be governed by some automated software systems promises to notably increase our quality of life. In fact, it will relieve us from a number of boring physical and mental activities, and enable us to do much more interesting things that, say, driving and having to decide on a route to a destination. In other words, it will make it possible to satisfy needs at the highest levels of the Maslow pyramid [9]. However, as we will elaborate in the following, algorithmic governance also comes with a number of potential dangers, and raises the risk of actually making us "dumber" rather than smarter.

Possible Perils of Algorithmic Governance

The primary source of all peril related to algorithmic governance is that, very often, software and algorithms are designed as "black boxes" with little understanding of how they actually work. This lack of understanding not only involves the final users (i.e., in case of smart cities, all citizens) but quite often also the stakeholders (e.g., municipalities and decision makers), and the developers, if they do not care enough to understand how these algorithms operate and have a discussion with designers and stakeholders.

This limited understanding of algorithms, from what we can see so far, does not prevent people from relying on them for various activities. For instance, people fully rely on Google's search results, even without knowing anything about its underlying PageRank algorithms. This is the key difference between algorithms and other classes of technologies: we are using them and relying on their judgement and suggestions without knowing the reasons we are being suggested something. In Smart Cities, a pervasive environment governed by algorithms will make us apparently smarter in our capabilities, but to some extent will also make us "dumber" in that our actions will no longer be conscious. For instance, roaming in an unknown city with a paper map enables us to absorb the basic fabric of the city and, on this basis, to consciously decide what route to take. Conversely, roaming with a GPS navigator does not require knowing anything about the city structure, and we are willing to accept route suggestions without investigating further the reason a certain route has been selected. In other words, our notion of "dumber" here is in the sense of potentially losing the ability to make good judgements in some situations, reducing discernment, and lazily deferring to the algorithm. The overreliance on algorithms, which are capable (unlike other technologies) of making judgements or decisions on our behalf, without our questioning or thinking them through, will make us increasingly depend on the algorithms in our everyday life, instead of depending on human rationale and our own reasoning.

One might say that the above issue will not cause any trouble because algorithms will be developed to serve citizens, for their own good and in accord with rules and policies of the municipality, and that such rules will be made transparent. Yet, as we elaborate in the following: 1) decisions made by algorithms may be biased and have inaccurate information; 2) there is risk that someone manage to make intentional misuse of algorithms without no one noticing; 3) politics and decision makers themselves may end up having little clue as to the actual working of algorithms, thus losing power.

With regard to the first issue, we normally trust the developers of the technologies we use, knowing that societal norms, regulations, and reputation largely help to protect that trust. However, intentional or (more often) unintentional bias, errors, or incomplete information, can subtly hide in algorithms, along with biases in behavior due to values (right or wrong) that developers or creators of the technology might have. This issue could be exacerbated by the increasing influence and role of technology in daily decision-making. For example, bias can creep into a machine learning algorithm [10] due to wrong or inadequate datasets, rather than any malice on the part of the developers (e.g., a system that is racially biased against people with black-sounding names when judging potential for crime, or software that could not do face recognition well for people with dark skin, or unfair judgments on insurance or loans, all due to issues with data used in training the algorithms). Also, what is a "normal person" or "normal behavior" is often contextual and hard to define — which can influence default settings in software [11], e.g., gender bias in default character profiles in some games, or someone struggling to read a critical alert message in a non-native language, or what an algorithm portrays as "normal looking."

Algorithms also could have incomplete information in decision-making or lack knowledge of exceptional cases even if developers do endeavor to be comprehensive. In some cases, even if tempted to doubt the algorithm, profitability in following the algorithm's decision can be high, but not necessarily by virtue of how good the algorithm is. For instance, with smart algorithms performing sentencing, or the "robotization of justice" [12], by deciding against an algorithm's position for guilt, one personally takes on the responsibility for a possible second offense. In any case, even if the thought that algorithms can do better than humans is becoming prevalent, and despite the recent breakthroughs in deep learning, for neural networks to achieve the computational level of a human brain, neural networks still need far more power [13].

With regard to the second issue, independently of the reliability and trustability of algorithms, there is an issue of who is devoted to managing such algorithms and of how we can trust those people to manage them. For instance, developers could be influenced by imperatives from (e.g., an abusive) government, when developing technology. If there is a problem with the current government, algorithmic technology could be intentionally misused, hiding behind the "veil of sophistication." In particular, if algorithms are left to their own devices to govern Smart Cities, the more complex conundrum is what algorithmic government models for Smart Cities should look like to prevent or mitigate voluntary or unintended abuses. Who will be in charge of deciding which algorithms to run? If politics are in charge of deciding the rules governing a city, who will be in charge of developing algorithms and to check that they are adhering to the rules? Who will tune the parameters for the algorithms and how? What about the possibility of instantiating multiple algorithms, and that such algorithms become antagonistic [14], i.e., conflicting with each other? What does an objective function for governance models look like? What does a termination condition for algorithmic governance models look like? Who will be responsible for bugs? For algorithms governing safety critical situations [31], such questions are already pressing, and this problem will be dramatically exacerbated in the future. Just think at the use of artificial intelligence (AI) and autonomous decisions in weaponry [15]. Hinton, in [13], also argued that there is not only a need to tame AI research, but also to improve political systems so that AI is not misused.

Strictly related, algorithms governing our cities may also be involved in decisions involving ethical or moral dilemmas. For instance, a human driver who managed to swerve her car in time to avoid killing several pedestrians while sacrificing herself might be lauded, but a self-driving car that killed its driver even while saving pedestrians might worry passengers [16]. Self-driving cars could reduce the need to learn driving, and so fewer people might end up knowing how to drive. This could be a problem in situations where such a skill is indeed needed. But moral algorithms that make human-accepted judgments are problematic. For example, an algorithm that behaves in a utilitarian manner could benefit society as a whole, but could hurt individuals, and therefore might not be accepted.

With regard to the third issue, the risk that politicians and governments lose control over algorithms, can lead to an "algocracy." The term "algocracy," contrasts with "democracy," and literally means that the power ("kratos" in greece) lies with the algorithms rather than with the people ("demos" in Greece). To some extent, it may appear we are already living in a partial algocracy, given that algorithmic decisions already affect some of our civil life. For instance, when applying for a visa for some countries, based on some business rules, applicants with a certain type of passport will receive immediate clearance, whereas others will be pushed to the next level of scrutiny. These procedures treat people differently based on the settings and semantics of algorithms. Yet until the settings and the semantic of such algorithms are perfectly compliant with legislation and rules, the power still resides with the government and, ultimately, in a democratic system, with the people who voted for them.

However, given that algorithms can be difficult to implement, configure, and fully understand, the risk exists that governments end up relying on algorithms they do not fully understand without being capable of effectively verifying the adherence of the algorithms to the existing laws. Thus, we may end up implicitly delegating decisional power to the algorithms, or to the group of people devoted to designing and developing them.

Algorithms in future societies and cities will serve the same role that civil law and urban regulations, respectively, serve in today's democratic systems. Accordingly, new political procedures need to be put in place to regulate which code is installed. The responsibility for (technical) code verification and (juridical) semantic verification needs to be clearly defined. Most importantly, to avoid having algorithmic governance degenerate into algocracy, it is necessary for citizens, politicians, and decision makers to become capable of understanding and harnessing the complexity of algorithms and their configuration.

How to Deal with the Problems

Let us now analyze what solutions, possibly enabled by the same pervasive computing technologies that cause them, can be envisioned to attack the identified problems.

Data Access Control

Algorithmic governance in Smart Cities is enabled by the availability of large amounts of data, making it possible for algorithms to understand what is happening and act accordingly. In this context, the dense and pervasive collection, processing, and dissemination of data in the midst of people's private lives, while useful for offering a range of sophisticated and personalized services that provide utility to users, necessarily gives rise to certain privacy and algorithmic concerns.

From the privacy viewpoint, the pervasive collection of information exacerbates existing issues associated with privacy in data handling. In fact, such details can be used to algorithmically construct a virtual biography of our activities, revealing private behavior and lifestyle patterns. Disclosure of this type of analysis or information gives rise to the notion of behavioral privacy [17] which is distinctly different from traditional identity privacy. The possession of such detailed personal information about an individual may confer power over that individual, resulting in potential misuse by governments, corporations, or other individuals. For example, households are being equipped with smart meters to act as providers of temporally detailed energy consumption reports. The utility companies use the data to better estimate domestic power consumption leading to optimized distribution. However, as shown in [18], several unintended and sensitive inferences such as occupancy and lifestyle patterns of the occupants can be made from the data. Accordingly, we need configurable privacy-preserving tools that afford users fine-grained control over how their personal information is shared.

From the algorithmic viewpoint, it is of fundamental importance for users to understand the type of personal information being used by algorithms to make decisions, and how such information is used. In addition, in cases where the user understands that such information is not correct, is biased, or is not appropriately used (and thus leads to incorrect algorithmic behaviors), the user can exploit the above-mentioned configurable privacy-preserving tools to adjust the usage of information by algorithms. For instance, consider an automated home heating system that self-regulates based on the life patterns of inhabitants (and bills accordingly), and a person who was constrained at home for 15 days due to a bad winter flu. When such person eventually goes back to work, he should be able to "see" if the heating system is still acting on the basis of the wrong assumption that he is at home with a flu. The risk, otherwise, is to lazily (and stupidly) accept paying more for heating.

For both concerns, pervasive computing technologies can potentially enable users to access the appropriate sensors (e.g., wirelessly via their mobile phones), and see what data they have produced, and how they have used what algorithms.

Algorithmic Guardians

If today algorithms affect what we can view online, tomorrow they will modify our physical reality at home or in a Smart City, and — as stated earlier — will do that in personalized way. However, even if we are offered the possibility of seeing what data is being used and by what algorithms, the resulting personalization process might not be transparent or comprehensible, and it could be hard to understand and interpret, especially for non-data-literate users.

Besides the problem of understanding personalization, another issue that may arise concerns the fact that personalization might not always serve the users' interest, but rather the interests of the algorithms' creator. There is usually an interest gap between you, theuser, and the third party that paid for the algorithms to prioritize something for you. This can lead to conflicts and obtrusive personalization. Different digital environments serve different interests and thus capture different areas of preferences. Algorithms generalize and simplify, as they continuously filter out details that are considered irrelevant or useless. In many cases, algorithms use other people's data to fill in missing bits and pieces.

Today our algorithmic selves are beyond our control and can leave us vulnerable. A possible solution could be to have software tools and algorithms that are on our side and under our control — algorithmic guardians — capable of somehow protecting us from undesirable behavior on the part of third party algorithms. We envision algorithmic guardians as far more evolved instances of current personal assistants such Siri, Watson, etc., that, thanks to wearable and advanced human-computer interactions models enabled by pervasive computing, will be always and easily accessible for interaction. Our digital guardian will protect us from algorithmic manipulation that restricts personal freedom and will make sure that we are not stuck on repeating behavioral loops or virtual echo-chambers. It will create an adaptive information interface that is fresh and relevant. Furthermore, guardians will support us in controlling our personal data flows and deciding who can access our digital trails. For instance, with reference to the home heating example in the Data Access Control section above, our personal guardian should be able to alert us that the heating systems is still acting as if we still had the flu, should help us correct such behavior.

Our digital guardian does not need to be intelligent in the same way as humans. It needs to be smart in relation to the environments it inhabits — in relation to the other algorithms it encounters. In any case, even if algorithmic guardians (unlike third party algorithms) are user-owned and are totally under our own control, being able to understand how they work will be a priority to make them fully trustworthy. This issue, which applies to all algorithms that will govern our life — is elaborated in the next section.

Democracy Through Grey-Box Code for Algocracy

Algorithms are created by a handful of people or, in a probable near future, by other algorithms that are created by an even smaller number of people. This raises an enormous challenge for our democracies.

In the spirit of "freedom of information," publishing the algorithms towards citizens seems like an obvious thing to do. However, this doesn't make a lot of sense if the overwhelming majority of the citizens cannot even read them. In today's democracy, civil law is also produced by a handful of specialists and to use it, we rely on lawyers. Nevertheless, the civil code can be consulted by anyone who is willing to make the mental effort of digging through some heavy prose. With the current literacy level of the general public in computer science, however, there is no analogue whatsoever for public understanding of algorithms. If rules and regulations were to be expressed in code, only a tiny fraction of today's society would be able to read them.

There is compulsory need, for both citizens and governors, be able to code the rules that govern the algocracy in a format that is understandable to policy makers and to the public. We also need to make sure that we will be able to understand whether the code is actually serving the purposes it has been built for, or if it is instead bugged or hacked. In this regard, we envision three key requirements: *better programming languages, inspectability of code, and users' computing literacy.*

Concerning programming languages, we emphasize that future algorithmic governance for Smart Cities needs to be inherently distributed and mobile. Accordingly, programming for Smart Cities will require much better programming languages than currently used for distributed programming where, for instance, there is little support for the verification of the current behavior of programs. This is confirmed by the tremendous amount of middleware that exists to cover the programs' shortcomings. Yet these middleware programs do not integrate well with the host language of the code [19]. Powerful languages that allow complex distributed code to be written in a "clean" way (such as AmbientTalk [20]) have not yet made it to the mainstream. What makes a "good" language for this job? An important yardstick for measuring the quality of a language can be found in Brooks' paper on complexity in software engineering [21]. Today's programming languages put far too much emphasis on the accidental complexity of a distributed system. Languages that allow a distributed programmer to only focus on the essential complexity are still being researched at this time.

For inspectability, algorithms are often referred to as "black boxes" in that it is not apparent to the casual observer exactly how the algorithm works. Tomorrow's intelligent environments and algocracies should be based on "grey box" systems that citizens can read and tweak along various "levels" of participation. Just like there is a distinction between a constitution and normal laws, distinctions have to be made between various levels of code so that some code can be easily tweaked by direct democratic processes (à la WikiPedia), whereas other code is proverbially carved in stone. In other words, the code that runs the algocracy needs to be exposed in a "grey box" fashion, where different shades of grey will probably be needed. For instance, in the area of pervasive computing and the Internet of Things, approaches to user-level programming for configuration of smart environments, based on simple and understandable "if this then that" rules (see e.g., www.ifttt.com), and hiding more mundane programming details, go in that direction of a "grey box" approach.

In a broader perspective, societal engagement would also include building "institutions and tools that put the society in-the-loop of algorithmic systems, and allows us to program, debug, and monitor the algorithmic social contract between humans and governance algorithms" [22]. The need for transparency, accountability, and explainability for the increasingly prevalent AI "black-boxes" has been noted in [23], where a layered model involving technical, ethical, legal, and social aspects needs to be taken into account.

In parallel with the development of an understandable "gray box" approach to programming, we need to solve one of the main factors hampering efforts for a healthy algocracy. This is the need for citizens to have at least a basic literacy in computing, and — if they are not able to program — they should be capable of judging the actions and the quality of the programs that govern them (at least when exposed in their "gray box" form). Unfortunately, computer science as a basic scientific field is absent in the high school systems of most countries. A notable exception is the U.K. where "Computing" is part of the high school curriculum since 2015. Even for people who will never program in their entire lives, a good basic understanding of what is programming, and what is an algorithm, is necessary for being a citizen in the algocracy!

Humans in the Loop and the Wisdom of Many

An algorithm is weightless and only worth the weight people put in it, so that some degree of safety from the potential dangers of algorithmic governance can come from the "wisdom of the crowd." There is a need for users to be able to provide feedback to the system in a forum, or through a mechanism for collectively commenting on the algorithm's performance, so that problems can be identified and signaled. The same pervasive sensing technologies that feed the algorithms with data can be exploited by users to monitor the environment and signal (and share information about) problems caused by existing Smart City algorithms. For instance, the fact that home heating systems are biased so that they do not meet user needs and only act towards some municipality goals, can be discovered by a multitude of users (or by their algorithmic guardians) by accessing sensor and actuator data. Eventually the users can then make the facts emerge to global awareness. Indeed, it should be a general goal for governments (at all levels, from national to municipal), whenever they start relying on algorithms to control cities and make decisions on our behalf, to involve human citizens in the loop at the highest levels of the participation ladder [3], i.e., as partners, in delegating authority, and as co-managers of the system or algorithm.

A different possible form of the wisdom of the crowd can be the wisdom of the crowd of algorithms, enabled by the existence of a plurality of algorithms and systems devoted to govern the same concern. In essence, human decisions might be based on some aggregation of the inputs of a number of preferably independent algorithms. That is, we can take the principle of the "wisdom of the many" to systems. However, when algorithms deal with ethical choices, the involvement of humans may become necessary. Should there be no time to involve a human in the decision-making, one can consider that some algorithmic decisions are premade by a human in advance so that human accountability is retained, and automatically adapted to the specific context once these decisions have to become actions.

Lastly, when there are systematic failures, there needs to be a way to "pull the plug." When an algorithm it is found to deliver unfavorable outcomes or cause problems, humans must be able to stop using the system. As a simple example, a user (as it is already indeed the case in our homes) should always be able to turn off an automatic home heating system and operate the system manually. The mechanism for control over these systems, and the way to turn them off, needs to be obvious [24]. However, for critical systems, the look and feel of the control switches needs to be different, so that unintentional, potentially fatal, mistakes are not made. As related in [24], control-room operators in a nuclear power plant found that similar-looking knobs could lead to a disastrous outcome, hence beer-keg handles were placed over them. Putting humans in ultimate control of algorithms would seem sensible, but is not without its own issues. For example, a human cannot simply switch off an autonomous vehicle when s/he thinks it is not performing up to its requirements — there needs to be a way to deliver control back to humans safely, and once in control, for humans to safely control the algorithm.

From Context-Awareness to Context-Control-Awareness

Pervasive computing technologies enable algorithms to make decisions that are context-aware, i.e., adapted to the context in which they operate (the already mentioned personalization being a specific form of context-awareness). Context-awareness has been studied since the 1990s in the area of pervasive computing [25], [26]. The last decade has seen dramatic progress in automatic recognition of context (including place — outdoors and indoors, human activity, habit, preference, and available energy and resources, etc.) and the self-adaptation of pervasive computing devices to the learned context.

Given the possible perils of algorithmic governance, one possible research direction is *"context-control-aware"* systems. That is, algorithms that can override control are not given full access for adapting the devices under their influence but are, instead, given a shared access control with a network of socially connected devices, with humans as co-decision makers, for shared governance [27]. This allows pervasive computing systems to be more "considerate," as they are not only aware of their contexts (and input to the systems), but also of how their influence and control (and the output of the systems) can bring unintended consequences. Such shared control should also account for safety, security, and privacy that — although extensively researched so far mostly in a separate silo — have yet to be integrated in context-control-aware systems for safer smart environments.

The issue of control (also related to the previously mentioned issue of "pulling the plug") involves that of making Smart Cities and environments really usable. This alludes to Steve Krug's attributes of usability of an interface [28]: useful, learnable, memorable, desirable, and delightful. In particular, the studied contexts in context-control-aware computing for Smart Cities and environments should also be provided with interfaces allowing citizens and end users to voice any discomfort and displeasure with the systems. This would enable higher levels of interactivity with the governing algorithms, and enable these systems to, e.g., "reverse action," "pull back," and activate "dumb mode" when required. We need Smart Cities to not just be "efficient." We also need to make it possible for citizens to be more interactive with the governing of cities, and vice versa [29].

There is a need for balance between a system that is too obtrusive to be useful, in which the user is too often involved, and a system that is too autonomous so that algorithmic regulation becomes real. A question is, can an algorithm be designed to compute this balance? Can an algorithm "solve" the problem of algorithmic dominance or governance, or of being context-aware, including an algorithm being aware of itself being too controlling? This is where potentially the pervasive computing community, in a close collaboration with other fields in this truly complex multidisciplinary issue, can contribute a solution.

Protecting the Individual Citizen from the Algorithm

The obvious advantage of the increasing availability of pervasive computing infrastructures is that they will make our lives much easier. However, this evolution also carries potential risks for individuals and for society as a whole. By blindly accepting the deployment of algorithms that run our society, we could become a "dumber" society or even lose control. In this context, "algocracy" may be nontrivial to reconcile with democracy. Dealing with these issues will require deploying a system of societal apparatuses to protect the individual citizen against the running code and/or against potentially malicious use by individuals of the data that is collected and produced by that code.

In this article, we have explored five avenues. 1) First, there is the obvious attention to data access control. Beside traditional privacy and security concerns, the notion of behavioral privacy will be equally important, as it will be the possibility for understanding how the exploitation of our personal data affects algorithms' behavior. 2) Part of the solution may be to proactively chaperone the ongoing activities of the algocracy with "algorithmic guardians" that can represent and defend us in the algorithmic world. 3) A less trivial challenge lies in making citizens aware of the code that runs their algocracy, and empowering them in novel democratic procedures that will be used to manage that code. 4) We should never give up the possibility for humans to "pull the plug" or to insist on the wisdom of a crowd of (preferably independent) algorithms. 5) Finally, context awareness could be used to "sandbox" the power of certain algorithms in certain contexts and to provide the meta technology to activate and deactivate the sandboxing based on a citizen's expression of discomfort.

We agree with [30] that ethical considerations must be central to new algorithms we will create in the future.

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