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Algorithmic governance: Developing a research agenda through the power of collective intelligence

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Abstract

We are living in an algorithmic age where mathematics and computer science are coming together in powerful new ways to influence, shape and guide our behaviour and the governance of our societies. As these algorithmic governance structures proliferate, it is vital that we ensure their effectiveness and legitimacy. That is, we need to ensure that they are an effective means for achieving a legitimate policy goal that are also procedurally fair, open and unbiased. But how can we ensure that algorithmic governance structures are both? This article shares the results of a collective intelligence workshop that addressed exactly this question. The workshop brought together a multidisciplinary group of scholars to consider (a) barriers to legitimate and effective algorithmic governance and (b) the research methods needed to address the nature and impact of specific barriers. An interactive management workshop technique was used to harness the collective intelligence of this multidisciplinary group. This method enabled participants to produce a framework and research agenda for those who are concerned about algorithmic governance. We outline this research agenda below, providing a detailed map of key research themes, questions and methods that our workshop felt ought to be pursued. This builds upon existing work on research agendas for critical algorithm studies in a unique way through the method of collective intelligence.

Keywords

Algorithmic governance, Big Data, algocracy, collective intelligence, interactive management, public participation

Introduction

We are living in an algorithmic age where mathematics and computer science are coming together in powerful ways to influence, shape and guide our behaviour and the governance of our societies. With the spread of surveillance technologies and the growth of the internet of things, we are creating a vast interconnected network of data collection devices (Greengard 2015; Kellermeit and Obodovski, 2013). This network produces ever-larger datasets of potentially useful information, updated in real time (Kitchin, 2014; Mayer-Schonberger and Cukier, 2013). No human being can

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make sense of this data unassisted. Hence there is significant reliance on algorithms to mine, parse, sort and configure the data into useful packages. Oftentimes these systems are maintained and tweaked by human designers and engineers, and the information is then utilized by humans in traditional corporate and bureaucratic decision-making systems. But there is also a growing willingness to outsource decision-making authority to algorithm-based decision-making systems. Some even dream of creating 'master algorithms' that will be able to learn and adapt to any decision-making situation without the need for human input or control (Domingos, 2015).

We can refer to these converging trends by using the label 'algorithmic governance' or, perhaps more provocatively, 'algocracy' (Aneesh, 2006, 2009; Danaher, 2016). Whether we like it or not, algorithms are increasingly being used to nudge, bias, guide, provoke, control, manipulate and constrain human behaviour. Sometimes this is beneficial; sometimes benign; sometimes problematic (Danaher, 2016; Pasquale, 2015; Zarsky, 2016). To ensure that it is more the former than the latter, an algorithmic governance system ought to be designed and implemented in a way that ensures both its effectiveness and its legitimacy (Peter, 2017). That is to say, we should ensure that it is an effective means for achieving some policy goal, whilst remaining procedurally fair, open and unbiased. But how can we ensure that algorithmic governance systems are both?

This article shares the results of a collective intelligence (CI) workshop we ran at NUI Galway in March 2016 that addressed exactly this question. The workshop brought together a multidisciplinary group of scholars to consider (a) barriers to legitimate and effective algorithmic governance and (b) the research methods needed to address the nature and impact of specific barriers. An interactive management (IM) workshop technique (Warfield and Cardenas, 1994) was used to harness the CI of this multidisciplinary group. This method enabled participants to produce a framework and research agenda for those who are concerned about algorithmic governance. We outline this research agenda below. We start by explaining some of the background to our workshop, placing its results in the context of the current literature on algorithmic governance. We then explain the methods and results of our workshop. Finally, we close by offering reflections on the research agenda proposed by the group. The proposed agenda is then provided in Table 2.

Context: Understanding algorithmic governance

The technological trends alluded to in the opening paragraph are relatively recent, but they have a deeper history. The phenomenon of algorithmic governance is part of a longer historical trend toward the mechanization of governance. Sociologists since the time of Weber have highlighted ways in which the legal-bureaucratic organization of the state is subject to the same modernising trends as the design of industrial factories (Kanter, 1991; Weber, 1947). The result is a system of governance that is machine-like in nature: tasks are subdivided and roles are specialized so as to perform the business of governance as efficiently as possible. This has always depended on the collection of data about the society and citizens to whom the system applies (Hacking, 2006), and from the dawn of the computer age attempts have been made to automate some or all of the process. Key figures in the cybernetics movement, for example, advocated the use of computerized systems of data collection, processing and decision-making in social governance (Medina, 2011; Morozov, 2014).

This does not mean that algorithmic governance is nothing new. The systems we consider in this paper and that we considered at our workshop are different from their historical forebears. The differences are largely a matter of degree and not of type. The technologies that facilitate the automation of governance certainly build on top of the pre-existing structures, thereby taking advantage of previous mechanistic innovations. But the speed, scale and ubiquity of the technologies that make algorithmic governance possible are grander now than they were in the past. Advances in machine learning and data collection enable the automation of processes that previously would not have been possible. They also enable far more efficient processing and handling of the data. Couple that with the fact that technologies of surveillance have become more deeply integrated into our everyday lives, and it seems that we are at a significant inflection point for the future of algorithmic governance. Many scholars have started to pay attention to this emerging reality and this has given rise to a burgeoning academic literature on the topic of algorithmic governance.

Our workshop aimed to contribute to and build upon this literature. Three aspects of the literature were of particular concern to us, specifically, the aspects focusing on (a) the forms/modes of algorithmic governance, (b) the problems of algorithmic governance and (c) the methods for studying algorithmic governance. We briefly describe these aspects below, noting how they shed light on the phenomenon of algorithmic governance, and how our study tries to build upon them.

The forms of algorithmic governance

The first trend concerns the *classification of different algorithmic governance systems*. Considerable work

has been done on identifying the key properties of the Big Data systems that enable contemporary algorithmic governance. Back in 2001, Doug Laney of Gartner proposed the now-classic 'three Vs' framework for understanding the emergence of Big Data systems. This framework suggested that Big Data was 'big' in terms of its *volume*, *velocity* and *variety*. Since then, more complex frameworks have been proposed (Kitchin and McArdle, 2016). Kitchin, for instance, has argued that there are at least seven dimensions to bigness, adding *exhaustivity, resolution and indexicality, relationality* and *extensionality and scalability* to the three Vs (Kitchin, 2014). These elaborations are useful insofar as they help us to grasp the properties of Big Data and better understand the challenges and opportunities it poses in the context of the design of algorithmic governance systems. That said, any classification system of this sort is prone to being value-laden and under- or over-inclusive (Kitchin and McArdle, 2016). This comment applies equally well to the other classification systems to which we refer below, and has implications for the definition and scope of algorithmic governance systems.

Another aspect of the ongoing literature relates to the classification of algorithms themselves. New algorithms are designed all the time, but they typically fall into a set of general types that have been exhaustively categorized by computer scientists (for a basic introduction see Cormen, 2013; for a more comprehensive one, see Cormen et al., 2009). For example, there are searching and sorting algorithms that break down into subtypes such as binary search, selection sort, insertion sort, merge sort and quicksort. Understanding these different types is important when it comes to assessing the social and normative properties of algorithmic governance systems. For instance, one of the most important high-level shifts in the design of algorithms in recent years is the move from 'top-down' algorithms (in which a programmer or team of programmers exhaustively defines the ruleset for the algorithm) to 'bottom up' machine-learning algorithms (in which the algorithm is given a learning rule and trained on large datasets in order to develop its own rules). This shift is important because the use of bottom-up algorithms creates certain problems when it comes to the transparency and opacity of algorithmic governance systems, particularly when such algorithms are incorporated into already-opaque governance structures. Awareness of this problem was part of the original motivation for our workshop and something that was repeatedly highlighted by the participants. A major goal, consequently, was to develop a research agenda that could address the consequences of this shift.

A final aspect of the ongoing literature on the classification of algorithmic governance systems is more explicitly evaluative in nature. It is primarily undertaken by ethical and legal theorists and focuses on identifying the key stages in the process of algorithmic governance and seeing how they relate to pre-existing governance systems. Four stages are identified by most contributors to this literature. They are *collection, processing, utilization* and *feedback* and *learning* (Citron and Pasquale, 2014; Pasquale, 2015; Zarsky, 2013). These stages are often said to define a governance 'loop': the system acquires information, processes it, uses it and then feeds back on itself by learning from what it has done (Carr, 2015; Citron and Pasquale, 2014; Zarsky, 2013). In this respect, an algorithmic governance system functions like a quasi-intelligent and adaptive system. From a normative perspective, one of the key concerns is to figure out how humans are involved in the different stages. Human participation in and comprehension of governance is typically deemed to be an important determinant of social and political legitimacy. And, of course, the impact of such systems on human behaviour is often key to their ethical and normative evaluation. Consequently, considerable attention has been paid to classifying systems on the basis of the type and degree of human involvement. Citron and Pasquale (2014), for instance, adopt a classification system utilized in military contexts to distinguish between systems in which humans are *in the loop*, *on the loop* or *off the loop*.

Identifying the problems with algorithmic governance

Although we did not seek to add additional complexity to these classificatory systems with our study, we found them valuable when it came to *understanding* and *identifying the potential shortcomings or problems* in the use of algorithmic governance systems. This is the second major trend in the current literature and the one to which we tried to contribute more directly. There are many proposed benefits to algorithmic governance, including speed, efficiency, comprehensiveness and fairness (Domingos, 2015; Mayer-Schonberger and Cukier, 2013; Zarsky, 2012). But there is also a growing field of critical algorithm studies which seeks to locate the social, ethical, political and legal problems that may be produced or reinforced by these systems (Gillespie and Seaver, 2016). There is a large and well-known literature on the privacy and data protection issues associated with the surveillance systems that underlie algorithmic governance (Polonetsky and Tene, 2013). There are several studies highlighting potential biases in the collection and utilization of data (Crawford, 2013; Kraemer et al., 2011; O'Neil, 2016). There are other studies expressing concerns about the emerging 'Big Data divide' which ensures that only large

institutions can realize the benefits of the data revolution (Mittelstadt and Floridi, 2016). There are many scholars talking about the opacity and lack of transparency that might be inherent in algorithmic governance, particularly when the governance system is driven by machine learning (Burrell, 2016; Danaher, 2016) and when it is protected by a network of secrecy laws protecting such algorithms (Pasquale, 2015). There are also concerns about the inaccuracies, inefficiencies and unintended consequences of these systems. All of these problems threaten to undermine the effectiveness and legitimacy of algorithmic governance.

Zarsky (2016) provides a taxonomy for classifying all the problems discussed in the literature to date. He argues that algorithmic decision-making systems have two key properties: they are potentially opaque and can be automated. He then argues that these two properties give rise to a particular taxonomy of objections. This taxonomy divides the problem space into two major branches: (i) an efficiency branch (which covers problems arising from the inaccuracy of decisions made on foot of algorithmic assistance); and (ii) a fairness branch (which covers problems arising from the unfair treatment of people under algorithmic governance systems). These branches break down into related sub-branches (prediction problems, bad data problems, unfair wealth transfer problems, arbitrariness problems and so on), allowing us to map out a reasonably comprehensive space of problems that could arise from algorithmic governance (see Figure 1). Being cognizant of these potential problems could, according to Zarsky, be a boon to future research.

While Zarsky's work on this is both helpful and insightful, it is largely the product of his personal, albeit highly-informed, perspective on the topic. One of things we sought to do through our CI workshop was to harness the insights of a group of scholars with diverse academic, applied and industry experience in an effort to map out a comprehensive problem space, specifically focused on barriers to legitimate and effective algorithmic governance. We expected that the barriers identified by our participants would complement those identified by Zarsky but would also provide a more disciplinarily diverse perspective on the problem space. Furthermore, we were conscious of the fact that Zarsky did not link his taxonomy of problems to an explicit research agenda for overcoming barriers to legitimate and effective algorithmic governance. This is something we explicitly attempted through our CI methodology.

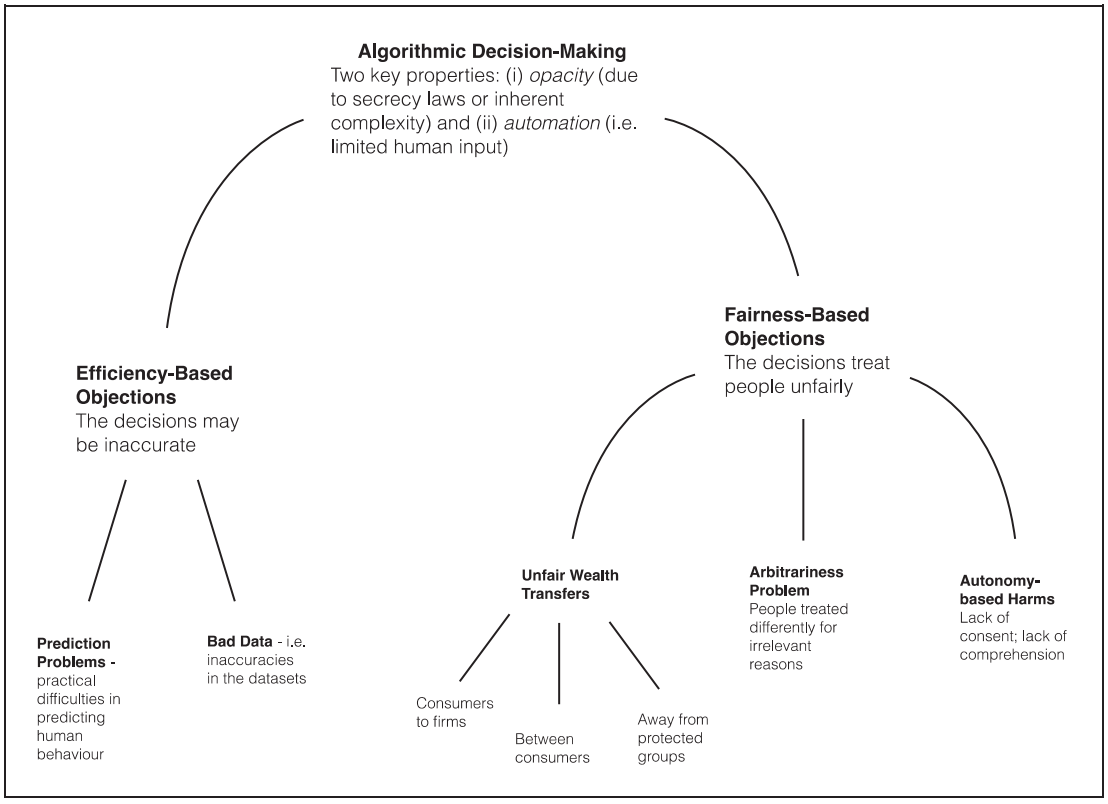

Figure 1. Zarsky's taxonomy of objections to algorithmic decision-making.[1]

Methods for studying algorithmic governance

This brings us to the final trend in the current literature, one to which we also sought to contribute more directly. This one relates to the identification of key *research questions* and *methods* that could further enhance our understanding of algorithmic governance and advance the critical algorithm studies agenda. There has been relatively little systematic work done on this topic to date. The most concerted effort is that of Kitchin (2017). He argues that a major goal of critical algorithm studies should be to better understand the processes through which algorithmic governance systems are designed and implemented. In particular, he argues that attention be paid to the 'translation' problems that arise when policy goals need to be converted into computer code. He then identifies three major challenges facing anyone who wishes to understand these processes and six potential methodological approaches for overcoming them. Each of these methodological approaches brings with it a number of plausible research methods. The result of this is the framework illustrated in Table 1. Note as you read it that the six methodological approaches do not map directly on to the three challenges but instead suggest a range of potentially useful research methods that might help to overcome those challenges.

Kitchin thus provides a useful starting point and framework for anyone wishing to do serious research in this area. Once again, however, the framework derives from the mind of a single scholar and is not the product of diverse disciplinary perspectives. Furthermore, it is not directly linked to a more comprehensive, categorised and coherent map of the problem space associated with algorithmic governance. Drawing upon the CI of a group of scholars, we hoped to provide, via our workshop, a more diverse, innovative and comprehensive framework of research questions and methodologies that is directly linked to a map of the problem space. This, we believe, will help to build upon and complement Kitchin's framework, and suggest ways to progress research in the area of algorithmic governance. We now turn to the methodology of our workshop and the results we obtained from it.

Methods – Collective intelligence

For our workshop, we used a CI methodology known as 'interactive management' (Warfield and Cardenas, 1994). This provided a systematic approach when working with the participants at the workshop to identify barriers to legitimate and effective[3] algorithmic governance and to develop a research agenda that would help to address these barriers.

IM was originally designed to assist groups in dealing with complex issues (Warfield, 1976). The theoretical constructs that inform IM draw from both behavioural and cognitive sciences, with a strong basis in general systems thinking. The IM approach carefully delineates what are known as 'content' and

Table 1. Research framework from Kitchin (2017)[2].

Research focus
- *Translation problem*: How is policy converted into code?

Research challenges
- *Black-boxing*: Algorithms are often proprietary. They are owned and controlled by companies and governments and their precise mechanisms are often hidden from view.
- *Heterogeneity and contextual embedding*: Algorithms are often created by large teams, assembled from pre-existing packages of code and embedded into complex networks of other algorithms.
- *Ontogenetic and performative*: Algorithms are not static and unchanging. They are often modified and adapted in response to user interactions; they develop and change in uncontrollable and unpredictable ways.

Methodological approaches and methods
- *Examining code*: Deconstruct code by sifting through documentation, map out algorithm genealogies, examine how the same task is translated into separate coding languages and run across different platforms.
- *Reflexively producing code*: The auto-ethnographic method, i.e. reflect on how you would convert the problem into a ruleset and associated code.
- *Reverse engineering*: Select dummy data and see what is outputted under various scenarios (e.g. testing Google's Pagerank or Facebook's Edgerank), follow debates among users, interview those who try to game algorithmic systems and so on.
- *Interviews and ethnographies of coders*: Carefully observing and interviewing members of coding teams as they construct an algorithm.
- *Unpacking the socio-technical assemblage*: i.e. discursive analysis of company documents, industry material, procurement tenders, legal standards and frameworks.
- *Studying real world effects*: Conducting user experiments, user interviews and/or ethnographies and otherwise exploring the social effects of algorithms.

'process' roles, assigning to participants to the workshop responsibility for contributing content ideas, and to the facilitator of the workshop responsibility for choosing and implementing selected processes, specifically, methodologies for generating, clarifying, structuring, interpreting and amending ideas. In an IM workshop, emphasis is given to balancing behavioural and technical demands of group work (Broome and Chen, 1992) while honouring design laws concerning variety, parsimony and saliency (Ashby, 1958; Boulding, 1966; Miller, 1956). IM has been applied in a variety of situations to accomplish many different goals, including developing instructional units (Sato, 1979), designing a national agenda for paediatric nursing (Feeg, 1988), creating computer-based information systems for organizations (Keever, 1989), assisting city councils in making budget cuts (Coke and Moore, 1981), improving the US Department of Defense's acquisition process (Alberts, 1992), promoting world peace (Christakis, 1987), improving Tribal governance process in Native American communities (Broome, 1995) and training facilitators (Broome and Fulbright, 1995). IM has also been recently used in a variety of basic science applications, for example, to design a national well-being measurement system (Hogan et al., 2015b), to understand the adaptive functions of music listening (Groarke and Hogan, 2015), critical thinking skills (Dwyer et al., 2014) and entrepreneurial competencies (Rezaei Zadeh et al., 2016).[4]

In a typical IM session, a group of participants who are knowledgeable about a particular situation (a) develop an understanding of a situation they face, (b) establish a collective basis for thinking about their future in relation to that situation and (c) produce a framework for effective action. IM utilizes a set of group methodologies, matched to the different phases of group interaction and the requirements of the situation. These include the nominal group technique (NGT), ideawriting, interpretive structural modelling and field and profile representations. The first two methodologies are used for generating ideas that are then structured using one or more of the latter three methodologies. Our workshop used a combination of NGT, ideawriting and field representations (see 'The process' section). To our knowledge this represents the first application of IM to examine barriers to legitimate and effective algorithmic governance and research that would help to address these barriers.

Participants

A total of 15 participants (10 men, 5 women) from diverse academic and industry backgrounds were invited to attend a CI workshop as part of an Algorithmic Governance conference at NUI Galway. All expenses relating to the event, including travel and accommodation, were funded by the Whitaker Institute at NUI Galway and the Irish Research Council. Participation was on an invitation-only basis. Participants were selected by the first and fourth authors. They were selected on the basis of their research interests and expertise, with a view to securing a reasonably diverse set of disciplinary backgrounds, and to achieving some reasonable balance representation from both genders. We did not succeed in achieving ideal balance in the latter regard but did succeed in achieving a minimal target of one-third female participants. More participants were invited (20) than could attend and participate (15), and two of the participants were self-selecting (we advertised the event within our own institution and to the colleagues of other invited participants and asked that people who were interested express their interest via email before receiving an invitation to attend). The backgrounds of the participants included computer science, law, library science, philosophy, geography, psychology, data science, political science and information systems. One of the participants was a former elected official, and several had some previous experience in the civil service. Three of the participants had a background in computer programming and had worked in industry. One of the participants was at the time employed by a company with a commercial interest in the technology, but this was declared and it was made clear that he was participating on a personal not a commercial basis. All participants were informed about the study procedure and gave their informed consent.

There are questions to be asked regarding the representativeness of the group. We sought participants on the basis of their academic and technical expertise rather than on the basis of other criteria. We reflect on some of the issues this may raise for the results of the workshop in the concluding section.

The process

There were four steps involved in the IM process: (1) participants were asked to generate and clarify barriers to legitimate and effective algorithmic governance using a modified NGT method, (2) the facilitators categorised these barriers to create a field representation of barriers, (3) the participants engaged in multiple rounds of ideawriting and group discussion to generate and clarify research options in response to barriers, (4) the resulting idea-writing sheets were transcribed and analysed to synthesise research options for a proposed research agenda.

The *nominal group technique* (NGT; Delbeq et al., 1975) is a method that allows individual ideas to be

pooled. A modified version of the standard face-to-face NGT method was used in the current study, with an initial pool of ideas gathered via email. The NGT method involved four steps: (a) participants were presented with a context statement and stimulus question (the question was 'what are the barriers to legitimate and effective algorithmic governance?') via email; (b) the participants generated five responses to this stimulus question by working alone and then sent their responses to the facilitators via email; (c) the facilitators recorded these ideas for posting on the walls surrounding the group at the workshop; (d) the participants engaged in a serial discussion of the listed ideas for the sole purpose of clarifying their meaning (during the first hour of the workshop).

The *field representations* were generated in advance of the face-to-face meeting and workshop with participants using the paired comparison method (Rezaei Zadeh et al., 2016) to compare barriers in pairs and identify categories of related barriers. Category labels were generated after related ideas had been grouped, with three interdependent coders working together to categorise a total of 57 ideas.

The *ideawriting* method (Paulus and Yang, 2000) was then used by participants to propose research ideas, along with stated methods and methodologies, which could facilitate understanding and help to address barriers to legitimate and effective algorithmic governance. Group members wrote their ideas on sheets of paper and exchanged them across an idea table, silently reading one another's ideas and adding to the idea set, prior to group discussion on the full set of ideas, and round-robin presentation of ideas to the facilitation team. Two trained IM facilitators facilitated the ideawriting session, which lasted for 2 hours.

Results – Barriers, research questions and research methods

Participants identified 12 major categories of barriers to effective and legitimate algorithmic governance (see Figure 2), and an additional challenge posed by the interdisciplinary nature of the topic. They also identified a wide range of research themes (see Figure 3) and methods (see Figure 4) that could be used to address those barriers. What follows is a description of all 13 barriers along with the set of research questions and methods participants proposed to address and overcome these barriers. This constitutes the research agenda proposed by the workshop.

Opacity of algorithms

One major concern that has emerged in the literature about algorithmic governance is the actual and potential opacity of such systems. The participants agreed that this is a problem, highlighting in particular how the lack of public and governmental understanding worked alongside intrinsic and manufactured opacity in the construction of algorithmic governance structures.

To address these problems, participants suggested that we try to get a better understanding of how algorithmic systems work: how they are coded and how they can be de-coded. Several research methods were recommended. Some participants suggested that we study coders as they programme and develop algorithms 'in real time', for example by following the coding process through live video-streaming services such as Periscope, or by 'crashing' (i.e. attending and observing) hackathons. Others recommended forensic analysis and ethnographic case studies to develop an understanding of how systems are developed, with a particular focus on how machine learning systems develop rulesets that end up being used in decision-making systems. Participants also recommended that we map out the stakeholder understanding of algorithmic systems, paying particular attention to the gap between public and expert understanding of how these systems work. This could be achieved through a combination of methods, including surveys, case studies, citizen science approaches, interviews and visual qualitative methods that graph what algorithmic systems 'look like' to affected communities. Participants recommended that we study more closely how these systems are used in governance and the impact they have on targeted communities and social groups. Again, interviews, ethnographic studies, comparative analysis and longitudinal studies were suggested as appropriate methods for this. Finally, one participant suggested that we develop an index of algorithmic transparency that could be used to scrutinize and assist in the development of algorithmic governance systems. The index could be modelled on similar indexes for political transparency developed by Transparency International and developed in partnership with such an organisation.

Techno-utopianism

Another barrier raised by participants concerned naïve techno-optimism or utopianism among politicians and technological stakeholders. This could lead them to rush into the widespread adoption of algorithmic governance systems without properly reflecting on their potential biases and negative effects. In addressing this barrier, participants felt there was a need to assess how widespread such techno-utopianism was and clarify its causes. The use of discussion groups and observational studies was identified as a way to map current attitudes toward these technologies.

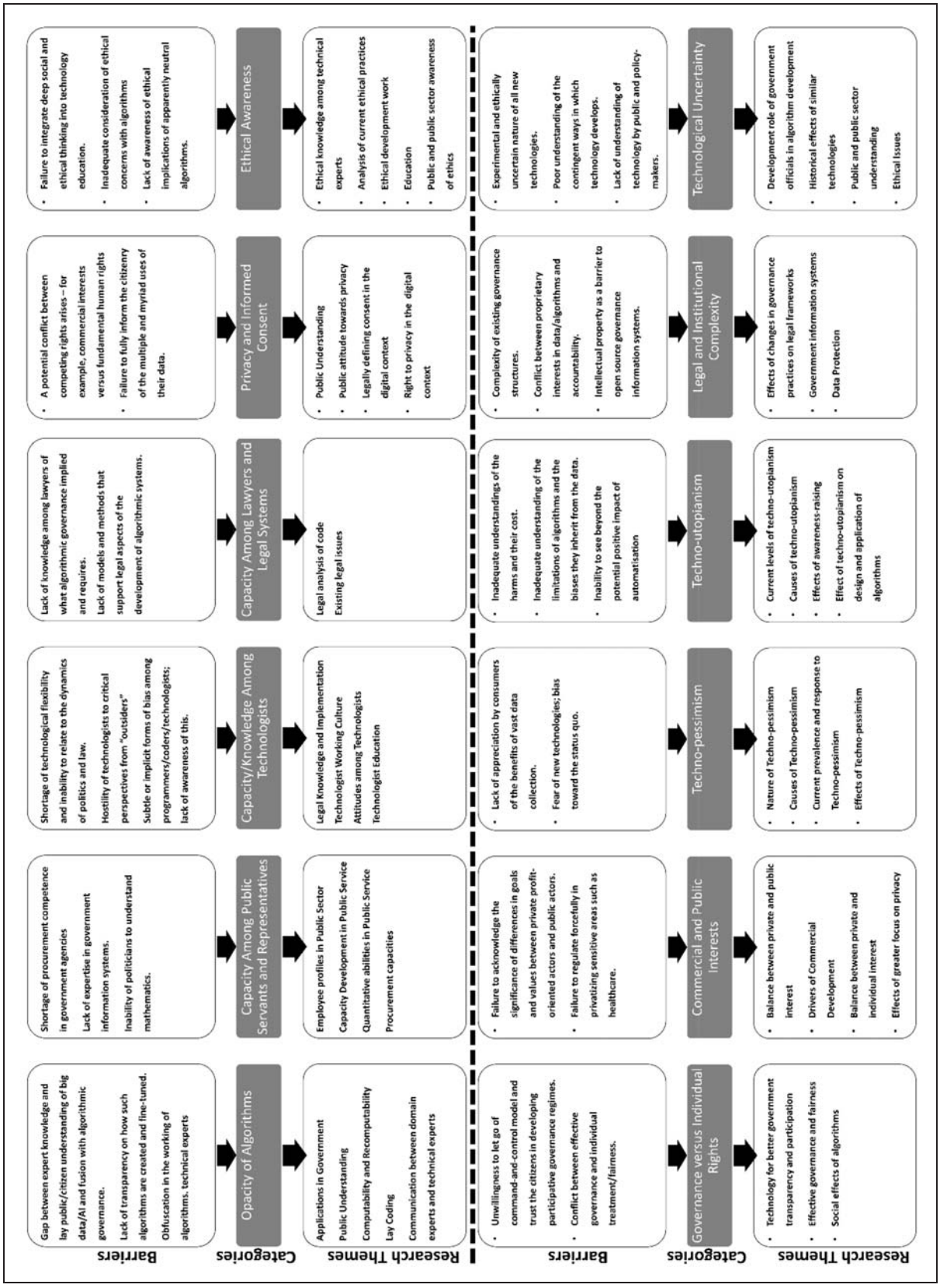

Figure 2. Categories of barriers to legitimate and effective algorithmic governance, including sample barrier statements.

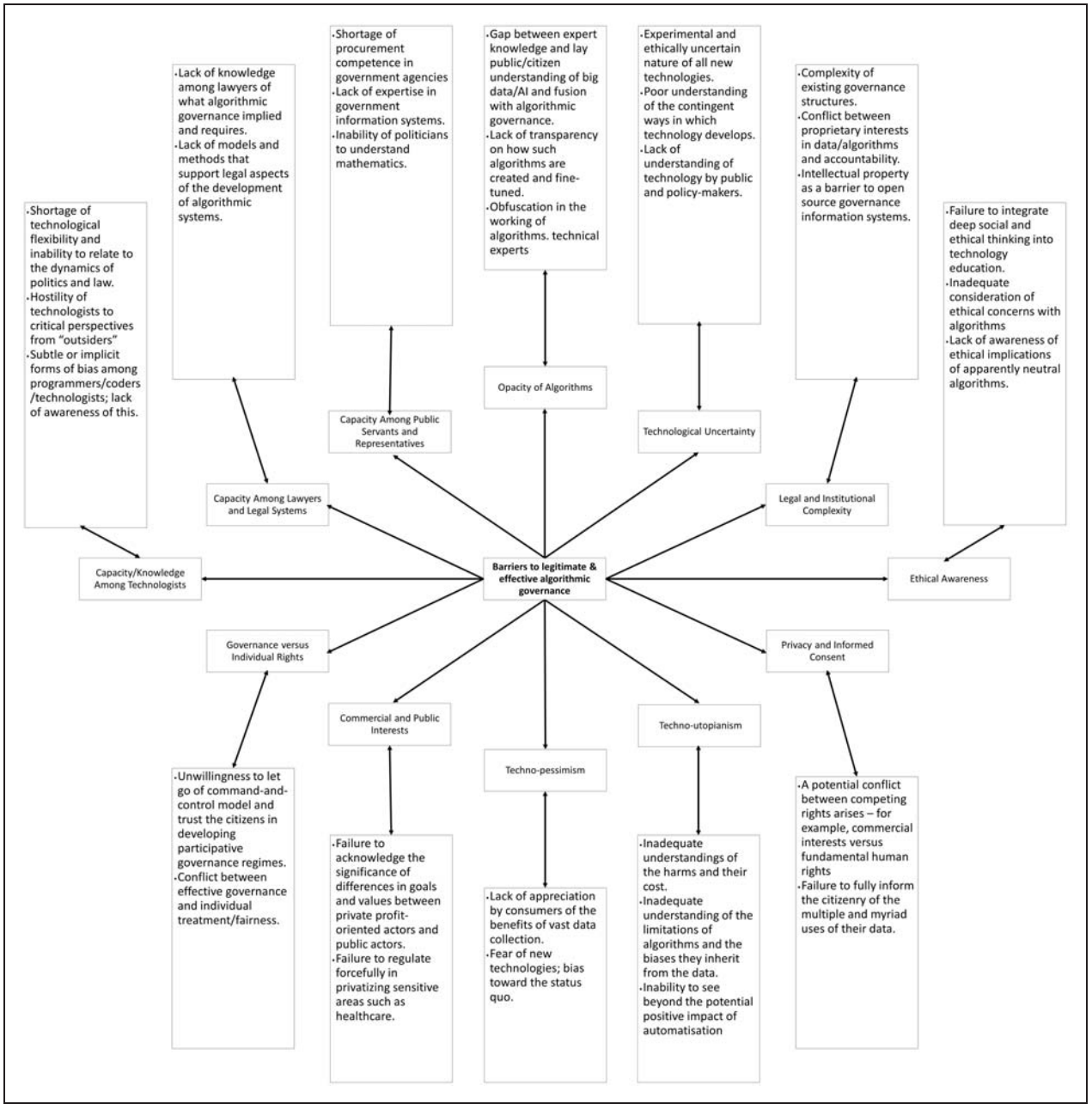

Figure 3. Key research themes in response to barriers to legitimate and effective algorithmic governance.

One participant suggested that we analyse speeches made by politicians and other key decision-makers to see how frequently they take-up 'popular science' ideas in their discussions of the technology. Careful analysis of cultural depictions and representations of the technologies was also suggested as being important when it came to understanding causes and origins of techno-utopianism. Participants felt it was important to understand the long-term effects of techno-utopianism with one person suggesting that a longitudinal corpus analysis could be used to map changes in emotional attitudes toward the technology over time. Observational and comparative case studies of coders, developers and relevant government agencies during the design and implementation of algorithmic governance systems was also suggested as a way to identify the limitations and biases that might result from techno-utopianism. In addition to this, participants felt we should explore various ways in which to raise awareness of techno-utopianism, perhaps through the use of video games and comics. In reflecting on these suggestions after the workshop, we would suggest that in order for these research methodologies to be effective, researchers would need a definition and clear measure of 'techno-utopianism'.

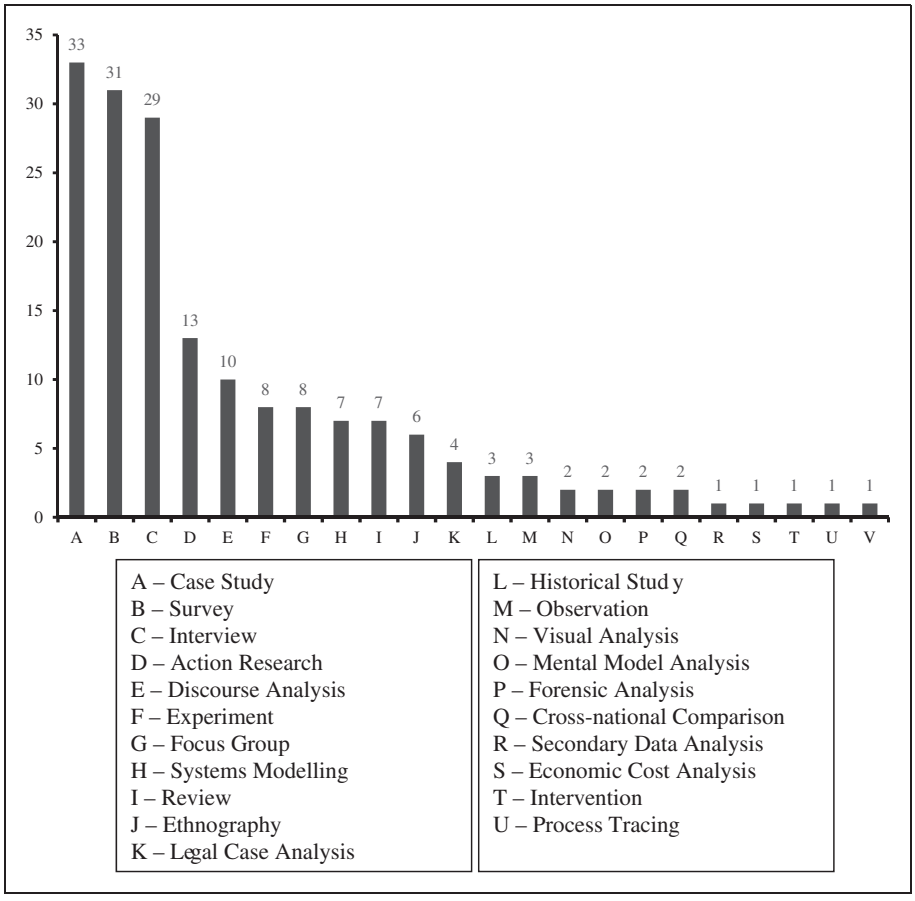

Figure 4. Frequency count of proposed research methods.

Techno-pessimism

Contrasting with the previous barrier, several of our participants suggested that pessimism regarding advances in technology could be a barrier to effective and legitimate algorithmic governance. They proposed several lines of research to understand more about such techno-pessimism. They identified a need to form a common understanding of what constitutes techno-pessimism, when it may be justified, and under what conditions it applies to one specific technology or towards technology in general. Participants suggested that we look at whether harms due to the proliferation of technological devices in young peoples' lives are evident. This could shed light on whether generalised techno-pessimism is justified. Investigations into the possible harms that algorithmic governance presents, such as defamation and damage to credit were also suggested when examining a more narrow type of techno-pessimism. Another suggestion was to examine analogous historical experiences of techno-pessimism in governance.

Following the development of a coherent definition of techno-pessimism, participants suggested that investigations into the prevalence of techno-pessimism, particularly amongst regulators, would be appropriate. This would require the development and validation of measures of techno-pessimism. The development of such measures would facilitate two further lines of research suggested by our participants, one of which would focus on the cause of techno-pessimism and the other on its effects. Participants mentioned specific causes of techno-pessimism that might warrant investigation. These were: negative experiences of technology, data protection hype, lack of knowledge, age effects, level of political engagement and the speed of release of technologies. Participants also mentioned possible effects of techno-pessimism which might warrant investigation, including the possible disadvantaging of certain sectors of society due to their fear of technology. Both quantitative and qualitative methodologies were proposed as suitable for progressing these lines of research, although a broader range of qualitative methodologies were suggested including interviews, case studies, focus groups and observational methods. Surveys and experiments were proposed as possible quantitative approaches.

Technological uncertainty

The apparent uncertainty regarding the effects of technological development was seen as a significant barrier to effective and legitimate algorithmic governance. Participants thought that the uncertainty had both subjective and objective dimensions.

On the objective side, it was suggested that, in general, we have a poor understanding of the contingent ways in which technology develops. This was linked in our participant discussions to the experimental and ethically uncertain nature of all new technologies. Proposed research strategies included investigating the effects of technological development from both a historical and ethical standpoint. The historical approach was seen as useful for examining the unintended consequences of new information systems, and for mapping the dynamic evolution of technology. One suggestion was to acquire all documents on a completed algorithmic governance system using a Freedom of Information request in order to examine how that system changed from development to implementation.

On the subjective side, technological uncertainty was seen as a matter of perception, caused by either a lack of technological understanding or lack of interest among the public and policy-makers. Participants suggested that our research strategies focus on ascertaining the extent of such uncertainty and its causes. They felt that research could be done to see how best to address it through interviews, focus groups and awareness-raising projects. Participants also felt that the lack of clarity regarding the contribution of government officials to algorithm development in the public sector was a significant source of technological uncertainty. This suggested there was a need to investigate how major e-government systems are developed and it was suggested that this could be done using ethnographic methods. Another suggested line of research in this vein was the investigation of how policy-makers work with experts and how governments ensure that specific expertise is factored into algorithmic decision-making.

Capacity/Knowledge among technologists

Technical experts wield a lot power when it comes to the design of effective and legitimate governance systems, but several of our participants worried that technical experts lack knowledge of the legal (and other) governance systems with which they interact. They also worried that such experts might be unaware of their own implicit biases and how they affect the coding process, and might be hostile to outsiders who lack their technical expertise.

To address these barriers, participants suggested that we get a clearer sense of the attitudes of programmers towards themselves, their work and those outside their discipline. In particular, they felt that researchers should figure out the extent to which technologists are developing their own internal culture and groupthink, the extent to which they resist critical outside perspectives, and their overall awareness of implicit biases. Developing this understanding could be achieved through case studies, surveys and interviews. Furthermore, since attitudes toward, and awareness of, law was a particular concern, our participants felt that research should focus on legal knowledge and reactions to law among technologists. This could include tests of legal knowledge, analysis of the extent to which programmers incorporate legal changes into their code, and the extent to which coders try to defend themselves from litigation in their coding decisions. Surveys, case studies and interviews were again suggested as the preferable methods. Finally, several participants recommended that we examine the educational background of technologists and consider the benefits of a broad life-long learning model for technologists.

Capacity among public servants and representatives

In a similar vein, several of our participants were concerned that a lack of competence amongst politicians and public sector workers could be a barrier to effective and legitimate algorithmic governance. The concerns varied from questions about mathematical abilities among politicians, to questions about procurement and information systems-capacities in public sector organisations. To research these barriers, participants suggested, in the first place, that we have some clear sense of the definitions of 'capacity' and 'competence' in the public service context. Clarity could be achieved by recruiting focus groups of public service workers to cluster and refine definitions. Understanding the extent of the capacity problem in the public sector was also deemed to be an important research priority. Participants said that research should focus on identifying the levels of competence needed by key decision-makers. This could be achieved through historical case studies of public sector organisations, qualitative and narrative interviews with key actors, interviews and focus groups analysing understandings of uncertainty, and comparative studies of different government agencies and private sector workers. Getting a better handle on politicians' competencies with mathematical reasoning and information systems was also deemed to be key research strategy. Finally, participants recommended that research should focus on how problems with competence arise and get managed within the public sector. In particular, they suggested that studies be conducted

on who gets recruited to the public sector, who gets decision-making authority, what is the relationship between the public and private sector, and how are people held to account when things go wrong. A number of methods were recommended in this regard, including actor-network theory methods, to map out relationships between individuals and social organisations, comparative and cross country analysis of graduate destinations, freedom of information requests to collate relevant information, and detailed case studies.

Capacity among lawyers and legal systems

If algorithmic governance is something that is ultimately made possible and held to account through law, then it is important to understand the capacity of legal systems and legal actors to manage it. Our participants were sensitive to this need, with several expressing concerns about the training of lawyers, the inflexible and conservative nature of legal codes, and the possibility of regulatory gaps opening up which prevent people from challenging the negative outcomes of algorithmic governance. To overcome these barriers, participants suggested that we survey the extent to which legal problems are already arising from algorithmic governance systems. This could be achieved by literature reviews and interviews with key legal figures (e.g. prosecutors or regulators). The creative exploration of possible legal problems was also recommended, with one participant suggesting that this could be achieved through experimental moot courts (mock trials). Participants also suggested that we identify capacity-related problems by analysing existing code and categorizing errors that emerge from this code according to whether they are 'technical' or 'legal' in nature. This could be enabled through case studies that combine interviews with document analysis.

Legal and institutional complexity

Complexity and a lack of transparency about algorithms are often deemed to be barriers to legitimate governance. Our participants expressed some concerns about how complexity in legal-bureaucratic systems that implement algorithmic governance systems could contribute to these problems. Several distinct worries were expressed. Some participants worried about the complexity of bureaucratic systems in themselves; some worried about the increased complexity resulting from the use of ICT within those systems; and some worried about the ways in which laws contribute to the lack of transparency associated with algorithmic governance systems. Participants recommended that research be undertaken to address each of these three concerns. Some participants suggested that we investigate previous and existing complexities in bureaucratic systems, using historical case studies, visual cartographies of the relationships between different organisations, process tracing, and comparative studies. One participant suggested that we take advantage of our experience with existing regulatory regimes that require the collection and tracking of environmental information and conduct a detailed study of how institutions respond to regulatory change. Others suggested that we focus on how ICT is adopted and deployed within bureaucratic systems. This could be done by comparing use of proprietary and open source systems in data-management, and by conducting a mental model analysis of key stakeholders that compare how they think ICT systems work with their actual operation. Finally, one participant recommended that we investigate the way in which algorithmic governance systems are described and framed in legal cases involving privacy and data protection issues. There are many cases on these issues already and they provide insight into how legal systems might cope with algorithmic governance more generally.

Commercial and public interests

The lack of balance between private profit-driven interests and public socially-driven interests was seen as another significant barrier. One participant noted that this lack of balance has led to a gap between the pace of the commercial development of algorithmic decision-making systems and the more limited applications in the public sector. The participant suggested that people in the private sector were reluctant to slow development in order to ensure effectiveness, as this would curb commercial success. Underlying this concern is the broader conflict between the values and goals of private and public bodies, which another participant said was not sufficiently acknowledged. They gave the example of the lack of regulation put in place following the privatisation of sensitive areas such as healthcare. A number of research strategies for investigating both the balance between commercial and public interests and the balance between commercial and individual interests were recommended. Regarding the former, participants suggested that the differences in perspective between government IT departments and private sector contractors should be explored through content analysis of e-government policy documents and the brochures and websites of vendors. This could help inform the development of a model of the goals and values of private and public actors. Regarding the balance between commercial interests and individual rights, participants recommended that we explore current attitudes and perspectives toward algorithmic governance and regulation, and raise awareness of

algorithmic governance. Participants identified a number of secondary data methods that could advance this research strategy. These included case studies and traditional legal and economic analysis research methods. Participants also identified a number of primary data methods, including public consultation, interviews, focus groups and surveys. The final research strategy recommended by participants in relation to this barrier was to examine the effects that a greater focus on privacy might have on the legitimacy and effectiveness of algorithmic governance. Participants suggested that the practice of 'privacy by design' be researched, and potentially followed up by awareness-raising training in commercial settings. Case studies of data overload could also be used to shed light on whether more data is always better. Furthermore, methods from economics could establish whether there are benefits to more discerning data collection.

Effective governance versus individual rights

Participants felt that, in considering the development of algorithmic decision-making technologies, care must be taken to ensure that a focus is maintained on individual rights and fair treatment, rather than solely on effective governance. For example, participants suggested that we prioritise research into the ways in which inequality and bias can be embedded in algorithms. A number of case studies already exist looking at this and it was felt that more should be undertaken. Participants also suggested that a key research priority was to examine the competition between efficiency and fairness in governance by surveying the public about their conception of effective governance. This could be combined with an investigation of into how technology can be employed to enhance government transparency and citizen participation. This strategy was suggested in response to the perceived apathy towards participative governance practices among political leaders. One participant felt that research into smart cities and their potential to enable participative governance would be a useful contribution to this research agenda. The piloting of blockchain technology as an alternative governance mechanism was also suggested as a means of increasing transparency and participation.

Ethical awareness (or lack thereof)

In relation to ethical awareness, participants highlighted inadequate consideration of ethical concerns with algorithms and failure to integrate deep social and ethical thinking into technology education as significant barriers. They also highlighted the lack of awareness of ethical implications of apparently neutral algorithms and the failure to recognize the political ethical dimensions of Big Data. In response to these barriers, participants suggested that it would be important to examine current levels of awareness and knowledge of ethical issues in the area of algorithmic governance among coders, politicians and the public. They highlighted the value of historical analyses and case study analyses in shedding light on how understanding of ethical issues developed in analogous domains (e.g. the development of medical ethics in the field of medicine) and how analysis of specific cases of algorithmic governance can shed light on key ethical issues in political decision-making. Participants also highlighted the importance of directly analysing the ethical consequences of algorithmic governance, for example, in areas such as predictive policing and profiling, where there is potential to perpetuate ethnic bias and social dynamics within communities. Related to this is the need for an analysis of the language of politics and Big Data studies, and how ethics are reflected in the language of agency, depoliticisation, and hegemony; and how political bias might be reflected in Big Data decisions. Analyses of ethical frameworks and existing codes of practice used in both technology education and Big Data applications was also seen as important, alongside an analysis of the ethical decision-making practices of data scientists and the ethical deliberation of politicians. From a technological point of view, participants proposed that we analyse the extent to which ethical development can be incorporated into machine learning. Participants also recommended some applied research goals, such as trying to write an open-source charter of algorithmic ethics and to investigate how research ethics committees are currently handling algorithms.

Privacy and informed consent

In relation to privacy and informed consent, participants highlighted inadequate privacy protections, failure to adequately protect human rights, dissonance between algorithmic systems and regulatory/legislative frameworks, conflict between the private and public interests, and failure to fully inform the citizenry of the multiple and myriad uses of their data as barriers. In response to these barriers, participants highlighted the importance of exploring the public's understanding of informed consent, their knowledge of the uses of their data and the uses of algorithms using surveys, interviews, vignette studies and laboratory studies. They also proposed case studies and survey studies designed to examine public attitudes toward convenience versus protection of rights (i.e. how willing are people to sacrifice privacy rights in return for cheaper and more effective services?). They highlighted the need to review the literature on privacy as defined in law and

the need to adopt cross-discipline studies that compare standards of consent in different legal fields.

The challenge of interdisciplinarity

The landscape of interdependent barriers outlined above, and the range and scope of research needed to understand and overcome those barriers highlighted, to all participants, the need for interdisciplinary cooperation. This was felt by most to be a generic challenge, present in many cross-disciplinary fields of research, but one that should not be ignored. Participants noted a range of issues that may have a negative effect on progress in this regard, including the dismissal of different perspectives in the field, a continuing knowledge gap and the lack of shared perspectives between technologists and others, which results in the under-theorised nature of both approaches to algorithmic governance. Participants highlighted a separation between domain-level experts and developers that led to systems that fail to match ethical and legal requirements. They noted that inadequate communication and lack of common language and cause among academics, policy makers and private sector actors, and lack of opportunities for deep multidisciplinary engagement, were also barriers to effective and legitimate algorithmic governance. In response, participants highlighted the value of survey, interview and ethnographic studies exploring competing attitudes of technologists and social scientists and the language used by different disciplines to describe similar phenomena. They proposed research focused on the nature of successful collaboration, and case study, document, and interview analysis of existing multidisciplinary projects and the iterative collaborative development of understanding. They highlighted the need for a review of available curricula, and interviews and surveys of students and teaching professionals to examine the form of training undertaken in different disciplines and how different educational practices may perpetuate difficulties associated with interdisciplinary communication. Participants highlighted the potential to theorize and establish a common approach to multiperspectivalism using collaborative writing methodologies. They also proposed the establishment of new networks of cross-disciplinary researchers who can work together to overcome interdisciplinary challenges and advance understand of effective and legitimate algorithmic governance.

Conclusion: Mapping the research agenda

We present the full map of barriers, research questions and research methods/strategies that was produced through our CI workshop in Table 2. We want to conclude by explaining the contribution we believe this map makes to the existing literature on algorithmic governance, highlighting the limitations of what we did, and identifying ways in which the research agenda we produced could be developed and enhanced in the future.

We can explain the contribution most easily by comparing what the workshop produced with the existing frameworks we discussed in 'Context: Understanding algorithmic governance' section. Consider, for instance, the frameworks that have been put forward by Zarsky (Figure 1) and Kitchin (Table 1). Zarsky's was a taxonomy of the problems that arise from the use of algorithmic governance systems. This taxonomy focused on two major categories of problems (efficiency and fairness), and broke those down into a series of sub-problems. The barriers identified in our CI workshop covered much of the same territory, with participants also highlighting specific concerns about inefficiencies, biases, lack of transparency and unfairness in the implementation of these systems. But the participants went much further than Zarsky, highlighting how the efficiency and fairness problems were connected to other problems in education, public understanding, technical competence, recruitment, institutional complexity, gaps in legal standards and more. The result is a much richer understanding of the problem space involved in this debate. On top of this, our participants linked these problems to specific research questions and methodologies and thus identified ways in which we might better understand these problems and contribute to their solution.

Something similar is true when we compare the results of our workshop with the research framework proposed by Kitchin. Where he highlighted one major focus, three research challenges, and six research strategies, our participants identified 12 major barriers to effective and legitimate governance and an additional challenge relating to multidisciplinary study, at least 48 distinct research questions, and 65 research applications. There is, consequently, a different level of comprehensiveness and breadth to the results of our workshop than is currently found in the literature. To be sure, our participants identified similar challenges and methods to Kitchin, but their collective efforts produced a more fine-grained analysis of the challenges, and a more complete mapping of the research that needs to be done to address each of these challenges. On top of this, we think they hit upon some interesting and novel research methods, including the use of live-streaming video to study coders as they code, partnering with political transparency organizations to create measures of algorithmic transparency, the construction

of visual cartographies and the use of actor-network theory to better understand institutional and legal complexity, among many other proposed methods.

Of course there are limitations to what we produced. It is important that anyone proposing to use our agenda is aware of that. One obvious limitation concerns the representativeness of the group involved. The research agenda we developed was the product of a particular group of people, working together over a particular period of time. There is no doubt that important perspectives were missing from what we did. As we mentioned in the 'Context: Understanding algorithmic governance' section, the participants were invited on the basis of academic and technical expertise and interest. Only one of the 15 was currently employed in industry, the remaining 14 were all currently employed in academic institutions. Some of those currently employed in academia had backgrounds in industry and government, and this was one of the selection criteria, but their current form of employment no doubt limited their perspective on the issue. On top of this, although there was some attempt to achieve disciplinary and gender diversity, other forms of representativeness were not sought. As the current research literature and our research agenda itself suggests, algorithmic governance systems may embed certain forms of bias and may disproportionately affect members of minority groups (ethnic, racial, sexual, disability-related, etc.). While some of our participants may belong to such groups, we did not select them for that reason and hence the absence of a more explicit recognition and engagement with minority perspectives means that there could well be gaps in what we have produced. We would defend the appropriateness of our academic-oriented selection criteria given that our aim was to produce a research agenda that would be useful to academic researchers, but there is certainly room for others to repeat the exercise with different groups and compare the results with what we have produced.[5]

Allied to this, the fact that the research agenda was produced by a particular group on a particular day means that our participants will undoubtedly have overlooked or ignored other possible research questions and methods. More work needs to be done to add-in the missing perspectives and fill-in the gaps, perhaps by reconciling and cohering our agenda with those already provided. A particular concern in this regard, and one raised by several of the reviewers on this paper, was the apparent absence of more critical/radical perspectives on the topic of algorithmic governance from our research agenda. It is worth noting that such perspectives are not entirely absent from what has been produced. The barriers originally identified by the participants consisted in statements/propositions, which we then grouped together and reduced to simple descriptive labels (such as 'opacity', 'techno-pessimism, 'public vs. private interests' and so on). Several of these statements[6] – particularly those relating to techno-utopianism, inequality vs. rights, and public vs. private interests – were quite explicitly radical/critical in their focus, challenging the more mainstream liberal political focus adopted by others. These statements were displayed to all participants on the day of the workshop on the walls of the room in which the session took place. Furthermore, the workshop itself took place after a more traditional academic conference consisting of short paper presentations. Several of these papers adopted a more radical and critical perspective on the topic and those perspectives continued to be discussed in the workshop session itself.[7] The research agenda we have produced (see Table 2) may seem to be shorn of those perspectives, but we would argue that this is not necessarily the case. We have reduced the discussions and conversations from the day to a series of reasonably concrete research questions and methods. We would argue that several of these questions and methods are open to those who wish to pursue a more radical/critical research agenda. That said, we certainly acknowledge that the way in which we framed the workshop (asking participants to focus on the questions of legitimacy and effectiveness) had a mainstream liberal/political orientation. We encouraged participants not to take this framing for granted in their contributions, but this could have affected the results we produced. We also acknowledge that we tried to facilitate dialogue at the workshop that represented the full range of perspectives of participants, including those that were negative or critical of the possibilities for algorithmic governance.[8]

Despite these limitations, we would argue that by harnessing the power of CI, we have produced the most comprehensive mapping of the research agenda to date – something that researchers can begin to use and develop right now. But no research agenda is ever complete and final. They are and should be subject to critique, iterative change and development. Future CI workshops of this sort could be used to facilitate further interdisciplinary collaborations on this important topic, perhaps by trying to represent different groups in the conversation and discussion. This is likely to be made necessary anyway by the fluid and rapidly-changing nature of the technologies underlying algorithmic governance structures. Nevertheless, we think the methodology we adopted to produce this research agenda, and the agenda that was actually produced, provide a firm platform on which future researchers can build.

Table 2. A research agenda for algorithmic governance

Barriers to effective and legitimate algorithmic governance	Potential research questions	Potential research applications
Opacity of algorithms	How are algorithms coded? Can they be decoded? How are they understood by those affected? How are they used in governance? How do they affect relevant communities? Can we measure the transparency of algorithms?	Study coders as they programme in real time using video-streaming services like periscope or at hackathons. Forensic analysis of algorithms (source code; pseudo-code, etc.) Ethnographic case studies of programmers Surveys, case studies, citizen science, interviews and visual qualitative methods to find out how stakeholders understand these systems. Interviews, ethnographic studies, comparative analysis and longitudinal studies of communities affected by algorithmic governance. Develop an index of algorithmic transparency, working in consultation with organisations who measure political transparency
Techno-utopianism	How widespread is techno-utopianism? How frequently are appeals made to techno-utopian ideals in political circles? What are the long-term effects of techno-utopianism? What are the limitations and biases that result from techno-utopianism?	Discussion groups and observational studies to map out current attitudes toward the technology Analysis of political speeches and cultural representations of technologies. Longitudinal corpus analysis to map changes in emotional attitudes towards technology over time. Observational and comparative studies of coders, developers and relevant government agencies during the design and implementation of algorithmic governance systems. Awareness-raising exercises of techno-utopianism through the use of video games and comics.
Techno-pessimism	Can we form a common understanding of techno-pessimism? When is techno-pessimism justified? Under what conditions is techno-pessimism narrowly focused on one technology or broadly focused towards technology in general? How prevalent is techno-pessimism? What are the causes of techno-pessimism?	Empirical investigations (surveys. interviews, experiments, etc.) of harms to people due to the proliferation of algorithmically-mediated devices. Investigation of specific harms resulting from techno-pessimism such as defamation and harm to credit. Historical case analysis of periods of techno-pessimism in governance. Surveys, experiments, interviews, observational studies and focus groups with regulators and other key figures involved in algorithmic governance in order to determine prevalence and causes of techno-pessimism.
Technological uncertainty	Do people understand the contingent and uncertain ways in which technology develops? What historical examples are there of unintended consequences arising from technological uncertainty? Can we learn from such examples? Is there a lack understanding and interest in technological development among the public and policy makers?	FOI requests and document analysis on all documents relating to the construction of an algorithmic governance system in order to examine how the system changed from development to implementation. Interviews, focus groups and ethnographic studies of policy-makers and technological experts as systems are developed. Interviews, focus groups, ethnographic studies and awareness-raising projects in order to track lack of understanding and the gap between expert and public knowledge.
Capacity/ Knowledge among technologists	Do technical experts lack knowledge of the legal and governance systems with which they interact? Are technical experts aware of their own implicit biases and how these might affect the coding process? Are technical experts hostile to outsiders who lack their technical expertise?	Case studies, surveys and interviews directed at: - Assessing overall awareness of implicit bias - Internal culture and groupthink among organisations building algorithmic governance systems - Understanding and knowledge of governance systems. - Figuring out the extent to which coders try to defend themselves from litigation in coding decisions Tests and quizzes of legal and regulatory knowledge.

(continued)

Table 2. Continued

Barriers to effective and legitimate algorithmic governance	Potential research questions	Potential research applications
Capacity among public servants and representatives	What does capacity and competence mean in the public service context? Do politicians and public servants understand how algorithmic governance systems work? What levels of competence are needed among key decision-makers when it comes to algorithmic governance? How do competence problems arise and get managed within the public sector? What is the relationship between the public and private sector? How are actors held to account when something goes wrong? Who gets hired in the public service to deal with algorithmic governance?	Focus groups of public service workers to cluster and refine definitions of capacity and competence. Historical case studies on capacity-related problems in public service. Narrative interviews and focus groups to assess needed levels of competence. Comparative studies of competence and understanding across government agencies and private sector workers. Actor network theory methods to map out relationships between individuals and social organisations. Comparative and cross country analysis of graduate destinations. Freedom of information requests combined with detailed case studies of competence failures/successes.
Capacity among lawyers and legal systems	What legal problems are arising from the emergence of algorithmic governance systems? Are regulatory gaps opening up as a result of algorithmic governance? Is the training of lawyers adequate to deal with the challenges emerging from algorithmic governance?	Case studies and literature reviews of problems emerging in existing litigation. Interviews with key legal actors, e.g. prosecutors and regulators. Experimental moot courts to explore new problems and gaps that might be arising. Analyse existing code and categorising errors that emerge according to whether they are technical or legal in nature. Combine this with interviews and document analysis.
Institutional and legal complexity	How complex are bureaucratic systems in themselves? Does the level of complexity increase as a result of increased use of ICT within bureaucratic systems? Do laws contribute to a lack of algorithmic transparency?	Historical case studies of bureaucratic complexity Visual cartographies to map relationships between different organisations, combined with process tracing and comparative studies. Study systems that already track and collate information (e.g. environmental regulatory systems) and conduct detailed analyses of response to regulatory change. Compare use of proprietary and open source systems in data-management. Conduct mental model analysis of key stakeholders in regulatory systems to compare how they think ICT systems work with their actual operation. Investigate the ways in which algorithmic governance systems are described and framed in existing legal case law on privacy and data protection.
Clash between commercial and public interests	Is there a reluctance to slow technological development down in order to ensure effectiveness and legitimacy? Is there a failure to acknowledge the clash of values between public and private bodies, particularly when algorithmic governance systems are being created? Are we/Can we balance commercial interests and individual rights? What are the commercial/public effects of a greater focus on privacy?	Content analysis of e-government policy documents and brochures and websites of commercial service providers. Economic and legal case studies of attitudes toward and use of algorithmic governance systems. Cost–benefit analysis regarding risks/rewards of greater data collection. Public consultation, interview, focus groups and surveys to explore existing attitudes toward and understanding of the values underlying algorithmic governance systems. Empirical investigation (interviews, ethnographies, surveys) of 'privacy by design' practices.

(continued)

Table 2. Continued

Barriers to effective and legitimate algorithmic governance	Potential research questions	Potential research applications
Effective governance versus individual rights	Is effective governance being pursued at the expense of individual rights and fairness? How can inequality and bias be embedded in algorithmic governance? How can technology enhancement government transparency and citizen participation?	More case studies on biased effects of algorithmic governance systems. Surveys of public opinion of what they understand by effective governance. Case studies of existing programmes (e.g. smart cities) to see how they facilitate transparency and participative governance. Pilot studies of alternative governance systems such as blockchain technologies to see if they facilitate greater transparency and participation.
Ethical awareness (or lack thereof)	What are the current levels of ethical awareness and knowledge among coders, politicians and the public? How are biases and ethical problems currently created through algorithmic governance systems? Could ethical codes for algorithmic governance be developed?	Historical and case study analyses of how understanding of ethical issues developed in analogous domains (e.g. medical ethics) Surveys, interviews and tests of ethical awareness among coders, politicians and public. Empirical studies (experiments, surveys, ethnographies) of the ethical consequences of algorithmic governance, e.g. predictive policing systems. Linguistic analysis of the language used in discussions of Big Data and algorithmic governance. Forensic analysis of existing codes of practice in technology education and Big Data applications. Empirical examination of ethical decision-making practices among data scientists and politicians. Develop machine learning models that can incorporate ethical learning – measure their effectiveness. Write an open source charter of algorithmic ethics.
Privacy and informed consent	How do the public understand informed consent? Do the public know how their data is used in algorithmic governance systems? Are privacy and informed consent protocols effective in protecting human rights abuses?	Case studies, surveys and interviews on public understanding of informed consent. Case studies and surveys of public attitudes toward convenience of technology versus protection of rights. Literature reviews on privacy and informed consent protections in law. Comparative analysis of consent standards across different areas of law.
Research challenge	Key question	Strategies for addressing the challenge
Interdisciplinarity	How do we ensure successful interdisciplinary collaboration on problems of this sort?	Case study, document analysis and interviews of existing multidisiplinary research agendas. Review curricula and interview and survey students and teachers across existing disciplines. Collaborative writing methodologies to theorise a common approach to multiperspectival research. Establish new networks of cross-disciplinary researchers.

Declaration of conflicting interests

One of the authors (Behan) works for a company (IBM) with a commercial interest in the type of technology being discussed. However, his contribution to this article is strictly in a personal capacity.

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Notes

1. This figure was created by the lead author of the current paper and is based on the discussion in Zarsky (2016). It was approved by Zarsky in correspondence with the lead author.

2. This table was created by the lead author based on the discussion in Kitchin (2017). It does not appear in Kitchin's original paper.
3. We focused on the concepts of 'legitimacy' and 'effectiveness' due to the fact that (a) they seemed sufficiently capacious to cover a number of concerns one might have about this technology, (b) were similar to concepts used in the pre-existing literature on the problems of algorithmic governance (e.g. Danaher, 2016; Zarsky, 2016) and (c) were broadly acceptable within mainstream liberal-democratic theory (Peter, 2017). We were conscious, however, that focusing the inquiry on these two concepts could bias/narrow the results of our study since they may be thought to exclude more radical and critical theoretical perspectives on algorithmic governance. To overcome this problem we encouraged participants in our workshop to feel free to question the conceptual framework that we used. We reflect on our successes and failures in this regard in the concluding section.
4. Groupwork methodologies have their problems. For example, the different processes used by a group to generate, critique and refine an idea set can lead to excessively convergent thinking and be excessively reliant on common knowledge (and hence not on the knowledge provided by the unique individual perspectives that are present in the group). We were conscious of these issues in the design of our workshop and the IM techniques we used (NGT, idea-writing, field representations) have been designed to overcome some of the common pitfalls of groupwork. For a longer discussion of the problems with groupwork and the techniques that can be used to address them, we recommend that the reader consult some of the second author's previously published work (Hogan et al., 2014, 2015a), as well as the very comprehensive discussion in Straus et al. (2009).
5. As one of our reviewers pointed out, there are issues even within academia concerning the representativeness of our group. After all, not everyone has the time to travel to attend and participate in a workshop of this sort. We tried to mitigate against this to some extent by ensuring that the event took place outside of teaching time (for the Irish participants) and during the ordinary working day. Just over a third of the participants were locally-based (i.e. attending an event that took place at their ordinary place of employment) so they should not have faced any greater difficulties in attending than they would ordinarily have faced in attending work. For those travelling from other institutions, difficulties in taking time out to attend would certainly be a greater issue and was the stated reason for most of the rejected invitations.
6. These statements are on file with the authors.
7. Approximately half of the papers were published in an abbreviated form in the September/October 2016 edition of the journal *Computers and Law*. The more radical/critical perspective is on display in at least one of these published papers: Morison 'Algorithmic Governmentality: Techno-Optimism and the Move to the Dark Side' – available at https://www.scl.org/articles/3714-algorithmic-governmentality-techo-optimism-and-the-move-towards-the-dark-side
8. Another issue, as one of the reviewers to the paper pointed out, has to do with the 'algorithmic' nature of the collective intelligence method. It might seem ironic and odd that we have used a quasi-algorithmic method for producing a research agenda about algorithmic governance. We appreciate this irony. But we think there are broad (any rule-following process) and narrow (a computerized, automated rule-following system) interpretations of what it means for something to be 'algorithmic'. Our research method was algorithmic in a broad sense, but we are not sure that it is algorithmic in the narrow sense and the narrow sense is the one covered by the proposed research agenda. Nevertheless, there is an interesting 'meta' research question to be posed about the method and whether it compounds or alleviates concerns about algorithmic (in the narrow sense) governance.

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