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Democracy by Design: Perspectives for Digitally Assisted, Participatory Upgrades of Society

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ABSTRACT

The technological revolution, particularly the availability of more data and more powerful computational tools, has led to the emergence of a new scientific field called "Computational Diplomacy". Our work tries to define its scope and focuses on a popular subarea of it, namely "Digital Democracy". In recent years, there has been a surge of interest in using digital technologies to promote more participatory forms of democracy. While there are numerous potential benefits to using digital tools to enhance democracy, significant challenges must be addressed. It is essential to ensure that digital technologies are used in an accessible, equitable, and fair manner rather than reinforcing existing power imbalances. This paper investigates how digital tools can be used to help design more democratic societies by investigating three key research areas: (1) the role of digital technologies for facilitating civic engagement in collective decision-making; (2) the use of digital tools to improve transparency and accountability in governance; and (3) the potential for digital technologies to enable the formation of more inclusive and representative democracies. We argue that more research on how digital technologies can be used to support democracy upgrade is needed. Along these lines, we lay out a research agenda for the future.

1. Introduction

This contribution is of relevance to the field of Computational Diplomacy and aims to give an overview of some recent developments in the area of "Democracy by Design". Computational Diplomacy is a relatively new field overlapping with Computational Social Science. It involves the use of computational thinking in the analysis and resolution of diplomatic challenges [1], and can help bridge the gap between the limitations of data-driven approaches and the complexities of real-world issues (see Section 1.2). It can, in particular, provide insights into how to use computational techniques alongside human decision-making processes. This serves to promote effective diplomacy, which considers a wide range of societal and ethical deliberations. While Computational Diplomacy can manifest itself in several forms, such as diplomatic network analysis, gamification of geopolitical crisis management, etc.,[1] the work presented here will primarily focus on digital governance, participatory democracy and value-sensitive design aspects of Computational Diplomacy see Fig. 1.

Digital Democracy is one of the significant recent research areas of interest to the field of Computational Diplomacy. This will be the main focus of our paper. Digital Democracy refers to the use of digital technologies in the political sphere [2]. It can refer to a wide range of activities aided by the Internet and other digital technologies that may be used to empower democratic processes. This can include online voting and petitioning [3] as well as digital campaigning and issue deliberation. Because the use of digital technologies in the political sphere is still in its early stages and constantly evolving, there is no one-size-fits-all definition of Digital Democracy at the moment. There is quite some variability among the definitions currently in use [4].

However, when discussing Digital Democracy, a few common themes stand out. These include using digital technologies to increase

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[1] https://www.lowyinstitute.org/the-interpreter/computational-diplomacy-science-art.

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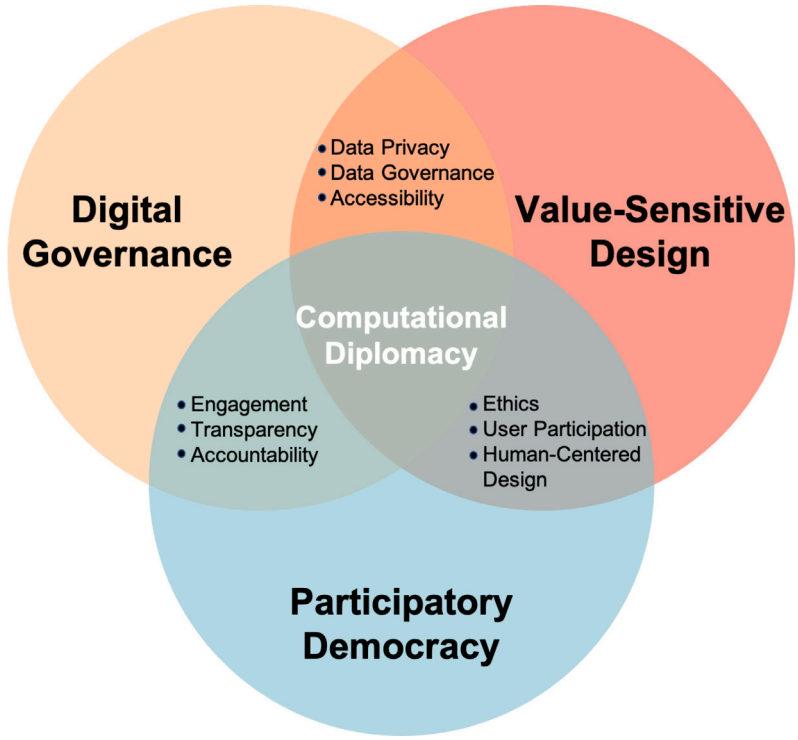

Fig. 1. Venn diagram depicting the specific topics addressed in this work, highlighting in particular the areas of digital governance, value-sensitive design, and participatory democracy. Although autocratic and technocratic forms of governance are also aspects of digital governance, they will not be the focus of our discussion. Rather, this work will emphasize the importance of digital governance, value-sensitive design, and participatory democracy in the context of Computational Diplomacy.

citizen participation in politics, make governance more accessible and transparent, and improve the efficiency of democratic institutions [5]. Digital means allow a higher level of participation [6,7]. However, current digital democracies also have some drawbacks. For example, it is easier to spread misinformation and hate speech online, and it can be challenging to ensure that everyone has equal opportunities to participate (e.g. due to the "digital divide"). Additionally, there are often concerns about transparency and accountability, security and trust.

Many people have believed the digital revolution would overcome the weaknesses of previous governance forms, by taking an evidence-based, perhaps even technocratic approach. In times of Big Data and Artificial Intelligence (AI), it is often suggested that new forms of governance would be feasible. For example, societies could now be run in cybernetic, data-driven ways. Some proposals go so far as to create a post-choice, post-voting society [8]. Accordingly, in an increasingly automated society, everything would eventually be "decided" by algorithms [9]. Some experts, however, doubt that algorithms make decisions at all when compared to the way humans take decisions.[2] The idea of using algorithms to govern society raises further questions about the role of human decision-making and the limitations of data-driven approaches. While algorithms can process massive amounts of data quickly and efficiently, they may not always be able to account for the uncertainty in decision-making from the complex social, cultural, and ethical considerations that shape our world. This is where the concept of Computational Diplomacy comes in.

1.1. Previous literature on Digital Democracy

The literature on Digital Democracy and participation has recently grown a lot and covers a wide range of topics, from Big Data to social media and communication technologies to value-sensitive design. Nowadays, there is an increasing emphasis on the potential of digital technologies [10,11] to help people participate and contribute to society in more effective and efficient ways. There is also greater recognition of the need for Digital Democracy and participation initiatives to be tailored to the specific needs and context of each country, region, or neighborhood.

To better understand the main themes within the literature on Digital Democracy and participation, we first performed a thematic analysis [12]. For this, we used a keyword search[3] in the Web of Science database to find relevant journal articles published in the last two years, which discuss Digital Democracy and participation. The search resulted in 140 papers. The search results were then used to identify the thematic evolution over two time periods, 2003 to 2015 and 2016 to 2022. As shown in Fig. 2, during the first period, research focused primarily on citizen participation, social media, and Digital Democracy. During the second period, the emphasis shifted towards using digital technologies to enable public participation in advancing Digital Democracy.

As the field continues to grow, Digital Democracy scholars are increasingly focusing on issues of inclusion and fairness, examining how new technologies can be used to empower marginalized groups [13], promote more inclusive forms of participation and upgrade democracies. Digital upgrades of democracies appear indeed to be appealing. As various references show, the subject of "digital democracies" has received increasing attention recently [2,4,5,14–19]. By now, it appears to be a trend in many countries to establish new forms of citizen participation, e.g. in participatory budgeting processes, and via the creation of citizen councils that discuss difficult political issues [20]. In the following, we will discuss a number of points that matter in this context.

[2] https://www.philomag.de/artikel/algorithmen-entscheiden-nichts.

[3] For "Digital Democracy" AND "Participat*".

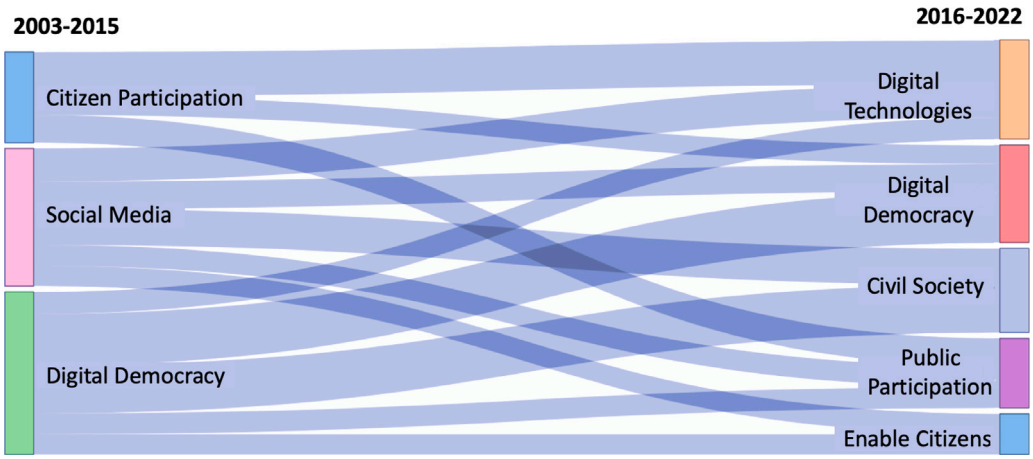

Fig. 2. Thematic map showing the evolution of literature related to the subject areas of "Digital Democracy" and "Participation".

1.2. Relevance of Computational Diplomacy

"Digital democracy" is one of the major areas of interest to the novel research field of "Computational Diplomacy", as the related research focuses on questions such as how to support consensus between people and/or stakeholders, how to enable better techno-socio-economic-environmental solutions, and how to promote a thriving, participatory, sustainable, and resilient society. Nevertheless, Computational Diplomacy will obviously (have to) care about other societal frameworks than democratic systems as well.[4] Overall, we expect that the following fields will be crucial for the area of Computational Diplomacy:

- Data Science (combining methods of data analytics with domain knowledge),
- Social Science approaches (including lab/online experiments, and political or communication science approaches),
- the science of Complex Systems ("Complexity Science", including Network Science),
- Computer-based Modeling (Game Theory, Agent-Based Modeling, etc.),
- institutional and mechanism design, and
- ethics.

These fields are also characteristic of the research area of "Computational Social Science". The main difference is that Digital Diplomacy would have a stronger focus on

- participatory approaches,
- the roles of negotiation,
- incentives,
- coalition formation, as well as
- legitimacy and trust,

to mention just a few examples. Altogether, however, the methodological core overlaps pretty much.

1.3. Relevance of Computational Social Science

Computational Social Science is a quickly expanding research area [21–23], even though it is relatively new. It has resulted from the increasing need of interdisciplinary studies and brings social, engineering, and natural sciences together. To some extent, it may be seen as a fusion of the social, computer and complexity sciences plus a couple of other fields. Socio-, econo-, and traffic physics have certainly contributed to this novel research area as well.

In this paper, we will present a preliminary summary of recent progress regarding how to promote democracy by design, using digital means. The approaches we describe take ethics on board by means of value-sensitive design or value-based engineering [10]. They are driven by questions from the social sciences and aim at better understanding social systems by means of scientifically guided data analyses or experiments. Such questions – or hypotheses about the way a system works – are often studied by means of computer-based modeling. This allows for the investigation of "what if scenarios", particularly the study of alternative interaction mechanisms ("mechanism design"). From this, new social mechanisms or other innovative institutional settings may result.

1.4. Design for values, value-based engineering

Our paper will take a "value-based engineering" [24] and "design for values" approach [25], also sometimes framed as "value-sensitive design" [26]. In other words, it will ask the question, how certain democratic values can be supported by digital technologies. "Privacy by design" is a well-known example of this approach [27]. However, people have started to considerably extend this approach beyond the subject of "privacy".

Creating digital systems involves many design decisions that have real-world consequences. Making such design decisions and assumptions should pay attention to democratic values, particularly when developing algorithms for the public sector. In fact, it has been recently demanded that digital technologies should be built in ways, which promote "Democracy by Design". In Fig. 3, we abstractly illustrate how iterations of design decisions may lose democratic values in the absence and presence of citizen participation during design decisions. To enable a fair procedure for making assumptions and parameterization of models in the public sector, we envision a future wherein the computational model creator informs the democratic value of assumptions and choices specific to value-sensitive designs—and elects those design decisions which maintain more democratic values to resolve intrinsic unfairness and bias introduced by a top-down approach to a computational model impacting people.

In connection with "Democracy by Design", it is relevant to ask what are the underlying values. In one of their featured projects, the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), for instance, has put a focus on equality, inclusivity, and freedom of choice,[5] calling for decentralization, separation of power (to prevent

[4] See, for example, this talk on Computational Diplomacy: https://www.youtube.com/watch?v=lH7WRBC1em8.

[5] https://amsterdamsmartcity.com/events/ams-science-for-the-city-5-democracy-by-design.

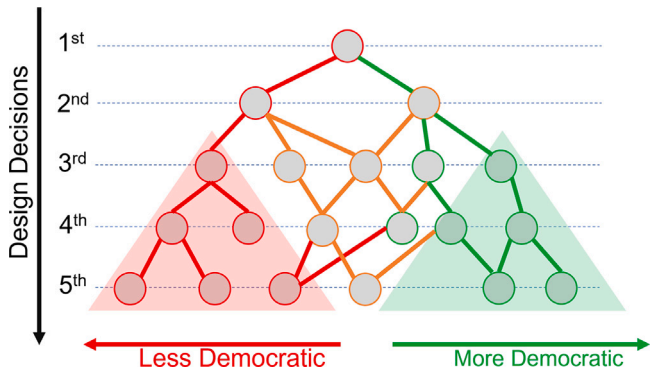

Fig. 3. Conceptual diagram of the process of value-sensitive design. Whenever alternative design decisions can achieve a similar desired functionality, one should take the decision that is better compatible with the value to be protected or promoted. Here, we illustrate a design process aiming to support democratic values.

conflicts of interest), and platform ownership by the users (besides a number of further points such as equal enforcement of Intellectual Property Rights, the minimization of data collection needed for a particular purpose, and a kind of Hippocratic Oath for IT professionals). In another paper [10], the following values have been highlighted: "[e]nvironmental conditions and health, safety and security, human dignity, well-being and happiness, privacy and self-determination (autonomy, sovereignty, freedom), fairness, equality, and justice, consensus, peace, solidarity, sustainability, and resilience". Despite its length, this list is certainly not complete, but still a good starting point for considerations around systems design.

1.5. Scope and structure of this paper

The remainder of this paper is structured as follows: Section 2 explores democracy by design, specifically how opinion formation can be improved through diversity, and by using digital tools and services that aid decision-making while reducing polarization and echo chambers. Through this exploration, we try to develop a more nuanced understanding of the role that technology can play in supporting or constraining democracy. In Section 3, we discuss how democratically designed systems can be more robust and adaptive because they allow for a wider variety of perspectives to be brought to the table. We further explore the concepts of adaptive services, infrastructure, and participatory design approaches. By having a people-centric design approach, we can create systems that are more responsive to the needs of individuals and communities.

Section 4 highlights that the concepts and tools discussed require both a trusted computing infrastructure and persistent data; distributed ledger technology can realize both. Section 5 delves into the benefits and drawbacks of digital assistance tools for Digital Democracy initiatives and governance systems. We discuss, why it is critical that digital assistance be designed in such a way that democratic values are preserved while also being resistant to misuse. Section 6 concludes the paper.

2. Democracy by design

2.1. Opinion formation

Let us start the discussion of Digital Democracy with the subject of opinion formation. What are values at stake, here?

While the US constitution appears to put a lot of weight on "free speech" (First Amendment of the United States Constitution), the UN Universal Declaration of Human Rights goes a step further. Its Article 19 states:

> "Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions without interference and to seek, receive and impart information and ideas through any media and regardless of frontiers".

In other words, the right to hold own opinions has at least three pillars:

1. The possibility to get access to relevant information with a reasonable effort (in particular, to the facts, which should be recognizable as such).
2. The chance to form an own opinion without being manipulated in that process.
3. Sufficient and appropriate opportunities to voice own opinions without fear of being punished, and without censorship.

In the digital age, all three of the above points call for improvements. For example, limited access to relevant data undermines the first point, as do dis- and misinformation ("fake news"). Opinion manipulation, e.g. by means of (big) nudging or bots, also undermines the second point [28]. We would further like to mention the problems of filter bubbles, attention harvesting, and information asymmetries. Last but not least, hate speech contradicts the third point. In fact, the "freedom from fear" principle is explicitly mentioned in the Preamble of the UN Universal Declaration of Human Rights ("human beings shall enjoy the freedom of speech and belief and freedom from fear").

The third point also implies that opinions should reach the public in a more or less *proportional* way, i.e. they should not be amplified or suppressed by algorithms. This is important for several reasons. First, there is a theoretical argument: Complexity Science knows many examples where symmetrical interactions lead to optimal self-organization [29]. Accordingly, while asymmetrical interactions may lead to relative advantages of some people over others, the system may get stuck in a local optimum. The global optimum reached when interactions are symmetrical may be better for everyone. Second, experimental research on Collective Intelligence indeed suggests that "the equality in distribution of conversational turn-taking" is a crucial factor determining the performance of human groups [30]. Also, the "group collaboration process is more important in predicting CI than the skill of individual members" (where 'CI' stands for 'Collective Intelligence') [31]. Third, in democracies, perhaps for such reasons, there are normative grounds for proportionality: "Equality" is a core constitutional principle, which is also reflected in the "one person one vote" approach.

The following paragraphs will address some of these issues in more detail.

2.2. Dealing with mis- and disinformation

The possibility of accessing free and unbiased access to information is a prerequisite of (deliberative) democratic systems [32]. Hence, mis- and disinformation, no matter if spread by people or algorithms, are serious threats to democracies. They can cause disorientation and undermine a constructive, fact-based discourse. Furthermore, they increase the information asymmetry between the people and those who have access to the facts, thereby creating an imbalance of power that is little compatible with democratic values and tends to promote conflict.

Disinformation means information that was fabricated to be misleading, for example, by "troll farms", while misinformation is inaccurate or fake, but not necessarily intentionally so [33–35]. By manipulating public opinion [36,37], disinformation campaigns can serve to destabilize democratic systems. Such campaigns may spread on traditional as well as social media [38], where rapid dissemination is promoted by the high connectivity of digital environments [39].

Governments [40] and scientists are now exploring new ways to effectively counter wrong beliefs in disinformation online and its spread [41–43]. As shown in Table 1, such approaches may be passive,

Table 1
The four main paradigms to combat misinformation.

Method	Example	Possible issues
Passive	Ignoring the spreaders	Misinformation can still spread
Reactive	Debunking	Backfiring and weakened cohesion
Pre-active	Spreading relatable news	Backfiring and weakened cohesion
Proactive	Teaching digital literacy	Is slow and requires commitment

reactive, pre-active, or proactive [38]. *Passive* approaches refrain from efforts to correct misinformation, so as not to increase its visibility [44].

Reactive approaches may take the shape of correcting mis- or disinformation with accurate information (usually called "debunking"). However, these corrections may not reach the visibility of the original piece of disinformation, or they may even backfire [45]. Reactive approaches undertaken by institutions include swamping social media with more truthful articles to introduce counterviews [46], while social media providers introduce fact-checking and labeling, platforming or filtering. However, a restriction of information by private parties and private interests is problematic. It must be scrutinized for its impact on democratic processes.

Prebunking is a *pre-active* approach grounded in inoculation theory [47], which aims to build resistance to anticipated misinformation exposure through preemptive contact in an analogy to medical immunization. Other pre-active approaches may involve targeting the source of disinformation or spreading truthful narratives in areas at risk.

Proactive approaches prepare public members to critically analyze and identify new information. Education, digital literacy, and numeracy effectively counter the belief in misinformation or conspiracy theories [48].

Another point to consider when discussing misinformation is social cohesion. Indeed, while most of the previously mentioned methods may counter the spreading of mis- or disinformation, they may also damage social cohesion. For example, it has been shown that conspiracy-like communities tend to avoid interacting with other groups [49].

Here, it is recommended to rely on methods such as digital literacy and digital enlightenment [50], allowing people to better *understand* news contents and their reliability. *Persuasion*-oriented methods, in contrast, may increase the divide in the population and reduce social cohesion, which is often not desirable.

Besides the above-discussed issues, one also needs to be aware of propaganda, mis- and disinformation using digital tools and bot networks. Unfortunately, it is not always easy to reveal the related bot accounts and their contents, as they are becoming more sophisticated. To some extent, there is an arms race going on between detection algorithms and algorithms to produce and spread mis- or disinformation. Filtering out suspected fake news by Artificial Intelligence systems is tempting, but has issues, as it introduces censorship, i.e. undermines free speech. In particular, this approach is not transparent enough with regard to the kind of information that is lost. According to the familiar "false positive" classification problem, there could be a significant fraction of truth in the deleted information. Therefore, an alternative approach to automated AI-based filtering of contents that is increasingly being used and a lot more democratic is to refer users to crowd-sourced content such as those at **Wikipedia** [51]. Involving competent, elected community moderators would also be an option.

2.3. Sustaining diversity

In pluralistic (democratic) societies, the existence of diverse opinions is considered to be valuable and important. It benefits societies in various ways, promoting, among others, innovation, societal resilience, and Collective Intelligence [52–55]. Hence, diversity should not be seen as a concession to individuals, but as systemic benefit.

While socio-diversity should be supported similarly to bio-diversity, current circumstances are not always well suited for this. Social Media often affect opinions in ways that reduce diversity. This may be counterproductive and can be changed.

It has been shown that a population's interaction network can profoundly affect the long-term behavioral diversity [56]. Some interaction networks, such as degree-heterogeneous networks, obstruct behavioral diversity. There, the population's diversity level is typically lower than if interactions were unstructured. Other interaction networks, such as highly clustered networks, favor behavioral diversity. There, diversity levels are usually higher than in unstructured populations. Generally, a network's propensity to sustain diversity depends on its topology in a way that can be captured by a "structural diversity index" [56]. This index also suggests approaches to change interaction networks such that they support more diversity. For example, unfollowing extremely popular people, represented in networks by high-degree nodes, can promote diversity (see Fig. 4).

2.4. Finding consensus

Political polarization is a major concern for modern democracies as it erodes social cohesion in favor of partisan interests [57]. This phenomenon can be so strong as to play a major role in the transformation of democracies into autocratic kinds of societies [58]. Indeed, in a polarized society in crisis, even people favoring democracy often elect politicians with an authoritarian governance style, if they promise to support their interests. (Whether these promises are being kept or not, is another issue, of course.)

While some people may think that polarization increases diversity and thereby benefits societies, it is actually the other way round. The term "polarization" is typically used to refer to cases, in which people are divided over a subject or issue [58]. This implies a lack of social cohesion. "Diversity", in contrast, means a distribution over many different subject areas, which does not have to contradict social cohesion. Polarization is often linked to extreme opinions [59] and has some fundamental effects on peoples' feelings. Indeed, "affective polarization" refers to the dislike between groups with opposite views [60], which undermines cohesion.

An example often discussed in connection with polarization is the United States [61]. There, democrats and republicans have become increasingly divided in recent years, while also liking each other less and less [60,62]. This has reached a point where only 4% of couples are between democrats and republicans [63].

Polarization is not restricted to classical political topics, but can affect many other aspects of everyday life as well (e.g. the adoption of new technologies and new habits). For instance, in the early days of Covid-19, it has been found that the two opposing political communities increased their polarization on topics such as trust in scientists and trust in charity workers [64].

At first sight, it seems that an obvious solution to this problem would be to apply methods fostering consensus. According to Edward Bernays, the author of the book "Propaganda", it is indeed possible to *engineer* public consent [65]. Despite its controversial uses in the past, the application of such methods is still common in the political area of "Public Relations", but in advertising and on Social Media platforms as well. With the availability of personal data, it has even become possible to individualize these methods, as it is being done with "Big Nudging" [66]. This makes the engineering of consent potentially a lot more effective, but it also creates opportunities to manipulate elections (see the Cambridge Analytica scandal) [67] . This has raised broad concerns.

Overall, given the potential for misuse, it is questionable whether one should strive to engineer consent in the future. Instead, we recommend to strengthen deliberative procedures that can promote consensus.

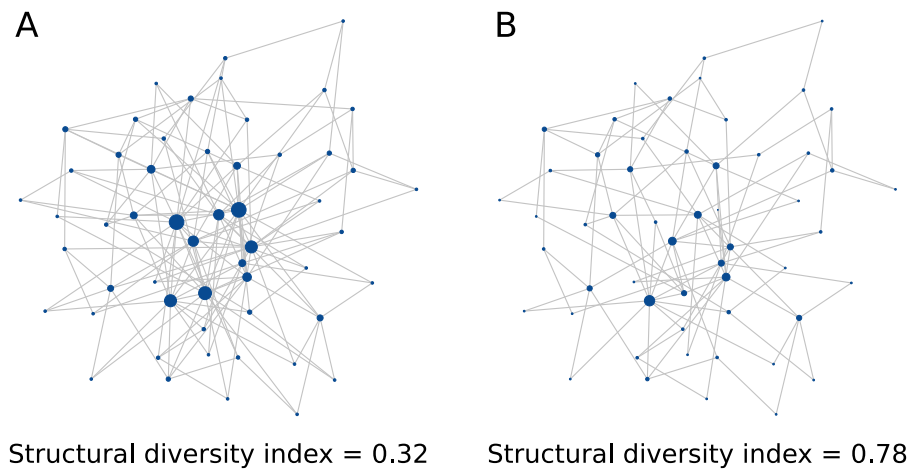

Fig. 4. Behavioral diversity is promoted by removing links to highly connected individuals. If each individual in the network (A) removes the connection to the most connected neighbor, one obtains network (B). The transition from network (A) to network (B) entails a substantial improvement in the network's capacity to sustain diversity, which is quantified by an increase in the "structural diversity index".

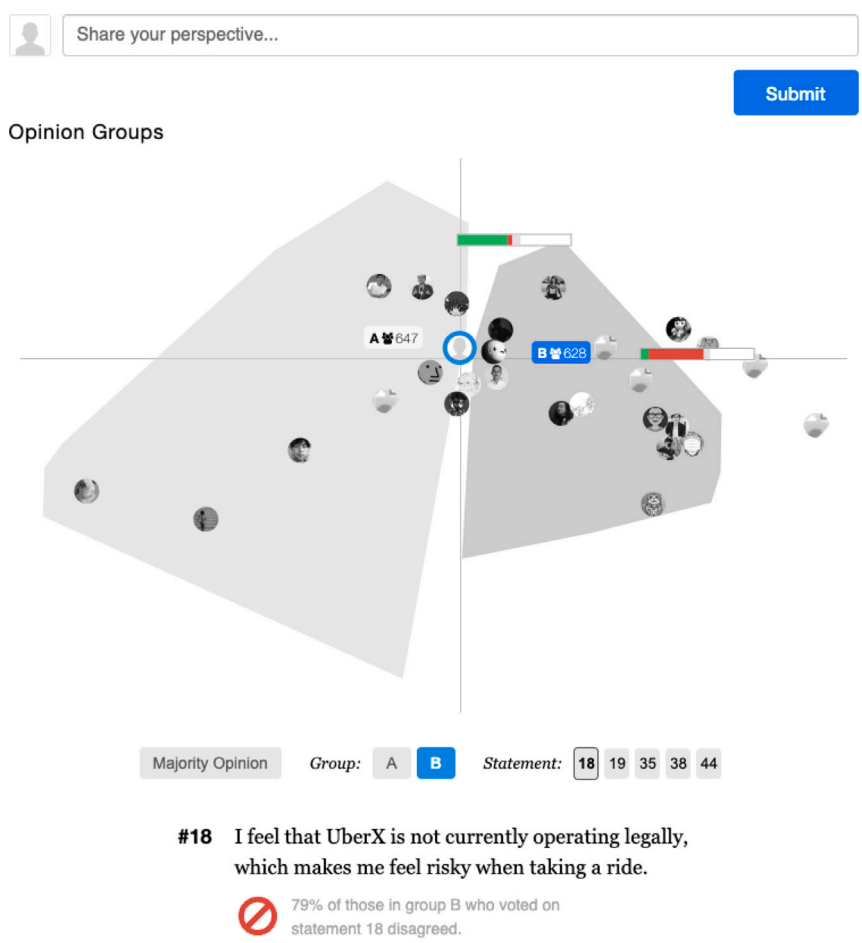

Fig. 5. vTaiwan's use of Pol.is for the discussion of Uber regulation.
Source: Screenshot from https://pol.is/3phdex2kjf.

In fact, there are now digital tools and technologies that can support human decisions and collective behavior in a meaningful way by enabling large-scale collaboration and exchange. For instance, in order to combat the lack of legislative transparency in Taiwan, starting in 2014, its civil society has gained experience in a number of initiatives and platforms that support coordination and cooperation. One of the more well-known examples is the **vTaiwan** platform[6] and its underlying system **Pol.is** [6]. The consensus-building platform allows citizens to set their own agenda for the conversation. Using upvotes and downvotes

[6] https://info.vtaiwan.tw.

to each statement, it visualizes opinions in real-time based on Principal Component Analysis, and it clusters people who voted similarly, using the k-means algorithm in a transparent manner.

As shown in Fig. 5, like-minded groups emerge quickly on the opinion map, transparently showing agreements and disagreements. People then naturally try to come up with comments that will win votes from different groups, thereby gradually overcoming the gaps. The platform gathers and analyses opinions, and offers high-level, actionable, and statistically significant insights. Instead of prompting further polarization, the process emphasizes constructive co-creation among diverse groups. Remarkably, the conclusion and insights of 80% of the discussed topics, such as the regulation of Uber or the FinTech Sandbox, led to decisive and successful government action.

By leveraging data-empowered methodologies, participatory models and digital tools, civil societies and governments around the world also benefit from new kinds of international collaboration and mutual learning.

2.5. Participatory Budgeting

In order to engage citizens directly in political decision-making, Participatory Budgeting, a process that involves citizens in allocating resources and monitoring public spending, has emerged as a democratic innovation [68] and successful participatory instrument [69].

Participatory Budgeting has been used in many cities around the world. Since the emergence of Participatory Budgeting in the 1990s, it has helped to confront problems of political clienteles and social exclusion. It has also increased political legitimacy by making the budgetary process transparent, open, and public [70]. Furthermore, it can be a good complementary measure to representative forms of budgeting, as Participatory Budgeting allows one to better address the diverse needs of underrepresented minority groups.

The standard process of most Participatory Budgeting programs follows similar procedures as the ones promoting Collective Intelligence (see Section 2.6), namely exploration, information exchange, integration of ideas, and voting. The approach helps to address the fact that societies in the digital era are becoming more and more complex. Collective action is increasingly individualized and issue-driven, apparently creating a new kind of "chaotic pluralism", which seems too dynamic and too complex to be addressed with traditional democratic processes or politics [71]. In order to deal with this, the idea of using Collective Intelligence via digital participation tools is rapidly gaining ground in cities around the world.

In recent years, the increasing use of digital technologies and platforms has enabled cities to include more citizens in a direct engagement with the collective decision-making process. Especially in Europe and parts of North America, the digitalization of Participatory Budgeting offers great opportunities for different stakeholders to effectively partake in large-scale political decision-making processes [72]. Europe accounts for over half of the Participatory Budgeting initiatives worldwide, with over 5000 schemes in 2019 alone [73]. The past decade also has seen the rapid development of open-source citizen participation platforms such as **Decidim**[7] and **Consul**,[8] which support large-scale Collective Intelligence.

Citizen participatory programs can be a useful tool for cities to identify issues on the ground in real-time, and to channel more resources to disadvantaged groups and territories most in need [74]. These new digital tools are increasingly being used to support citizen participation in an open culture, thereby strengthening democracy, as well as to support cities and institutions in meeting the demands of accountability and transparency [75,76].

Digital Participatory Budgeting has also played a pivotal role in fostering communication and cooperation between cities, paving the way for a new era of Computational Diplomacy. Through the exchange of experiences, best practices, optimal platform design, and insights, cities can learn from each other's Participatory Budgeting initiatives and adapt successful strategies to their local contexts. The growing adoption of digital platforms, such as **Decidim** and **Consul**, has also facilitated this type of sharing of information and resources, enabling cities to collaboratively tackle complex urban challenges. By embracing Digital Participatory Budgeting, these cities are not only empowering their citizens to actively participate in the budgetary process, but also to build a global network of interconnected urban communities. This digitally enabled "urban diplomacy", characterized by open communication and co-learning, strengthens democracy, promotes transparency, and ultimately enhances the efficacy of Participatory Budgeting initiatives worldwide.

2.6. Collective intelligence

Complex dynamical systems such as social systems often show a feature characterized as "the system is more than the sum of its parts" [77]. This observation is a consequence of non-linear or network interactions, and refers to self-organization effects or emergent properties observed in many complex dynamical systems. A particularly interesting phenomenon of this kind is "Collective Intelligence" [30] (sometimes also called "the wisdom of crowds" [78]), which is a generalization of "swarm intelligence" [79].

"Collective intelligence" refers to the fact that a combination of various solutions often outperforms the best individual solution. That is particularly true for complex problem-solving, where it is important to combine different perspectives to get a fuller picture of a problem and its possible solutions. However, "Collective Intelligence" does not result automatically. It has a number of preconditions, particularly that people (re)present a sufficiently diverse set of solutions. Hence, a lack of diversity can imply poor solutions.

The following procedure appears to be favorable for the emergence of "Collective Intelligence" [80]:

1. *Independent exploration:* The first phase consists of the search for information and solutions. This search should be independent from that of others and not externally manipulated.
2. *Information exchange:* The second phase serves the exchange of information about the solutions found.
3. *Integration:* In the third phase, various solutions are combined in an innovative way by means of a deliberative process.
4. *Voting:* In the fourth phase, the people affected by the problem vote to determine the best-combined solution.

This is in line with insights into what enables successful deliberative public opinion formation processes [4,81].

Digital tools can support all four phases listed above. For example, the search for information and the exploration of the solution space may be promoted by suitable incentive systems [82]. Additionally, one may consider different voting methods. The best choice may actually depend on the problem to be addressed [83].

2.7. Voting

2.7.1. Electronic IDs

Discussions on voting in digital societies have recently revolved around the subject of electronic IDs (e-IDs) and the possibility to avoid paper ballots. Related to this, however, there are a lot of concerns that democracies might become "hackable", i.e. election results could be biased.

Furthermore, there have been fierce debates about how an e-IDs should work [84], what biometric features they should use, and who should be responsible for managing the related platform(s) and data.

[7] https://decidim.org/.
[8] https://consulproject.org.

In our paper, we would like to stress instead that there are other, probably more important points to consider when it comes to voting. Namely, it is possible to apply different voting rules to determine the outcome of a vote, and this can make a significant difference.

2.7.2. Voting systems

Voting aims to solve collective decision ("social choice") problems when there are many different opinions, interests and needs at play. Therefore, Computational Diplomacy and voting methods are tightly connected. Both are highly important in decision-making, consensus-building, and conflict resolution across various political and international contexts. In particular, voting methods and their legitimacy are essential to finding effective solutions between different interest groups, which are broadly supported.

A well-configured voting system should promote an effective participatory process and a fair outcome. This requires that voters can adequately express their preferences through votes. The "input method" defines the way this is done. The "aggregation method" then translates the votes into a collective decision. While these methods have been well studied in theory, it is also crucial to consider the user perspective for successful practical implementation, such as in diplomatic negotiations or Participatory Budgeting settings.

We will now examine both input and aggregation methods, focusing on two aspects that can sometimes be contradictory: the theoretical characteristics and the user's perspective on these methods. By addressing these aspects, we aim to create a more comprehensive understanding of how voting methods and diplomacy can be brought together to promote fair and inclusive decision-making processes.

A notable disparity between the usability of an *input method* and the desirability of its outcome was recently observed in a laboratory experiment investigating Participatory Budgeting. Among the five input methods examined, participants found k-approval to be the most user-friendly. Regarding consistency of votes and response time, k-approval outperformed all other input formats [85]. However, voters felt that k-approval was the least effective in reflecting their preferences, for which ranking by value was considered the best approach. This finding is highly relevant for diplomacy and underscores the potential gap between factors that contribute to the usability of an input method and aspects voters perceive as crucial when casting their votes.

Note that the choice of input method may promote a particular outcome. One related aspect that is especially important is to avoid a "winner takes all" effect, also known as the threat of a "Tyranny of the Majority" [86]. The more diverse or complex a society becomes, the more important this may be. *Quadratic Voting* [87] aims to prevent such undesired outcomes [86] and has gained some traction for collective decision-making and blockchain governance [88]. It differs from traditional voting methods by allowing voters to express the intensity of their preferences using voting credits. The decision cost is then calculated as the square of the number of votes cast. By making it "expensive" to choose only one option, Quadratic Voting helps to protect minority interests and encourages diversity. Diversity, in turn, strengthens Collective Intelligence 2.6; Therefore, voting innovations that ensure diverse outcomes deserve serious consideration.

It is crucial to recognize that, besides the input method, the choice of *aggregation method* can also significantly influence a vote's outcome. A study comparing five aggregation methods within a laboratory experiment has recently revealed differences in participant assessments of aggregation methods [89]. (Specifically, when considering a *set of projects*, maximizing the Nash product[9] appears to be the most appropriate method. In contrast, when evaluating *verbal explanations*, maximizing utilitarian social welfare is deemed the most suitable aggregation method. Another study found that an aggregation method ensuring that at least one of the citizen's preferences is realized increases voter participation [90].)

Consequently, selecting suitable and trusted input and aggregation methods may be considered an important tool in the Computational Diplomacy toolbox. When the effectiveness of a collectively decided solution relies on continuous support from the broader public, the solution must be perceived as legitimate and reflective of the voter preferences. As a result, the perception of an input method is of great importance. Moreover, diplomats are advised to employ quadratic voting in diplomatic negotiations on topics with a high risk of a large group dominating a smaller one. Last but not least, diplomats should prioritize an aggregation method, ensuring that at least one of the citizen preferences is realized. This can encourage broader engagement in the decision-making process and support inclusion and legitimacy.

2.8. Legitimacy, trust and transparency

When choosing the input and aggregation method, from a democratic point of view, it is key to put a particular focus on the perceived *fairness* of the voting outcomes. Decisions about sensitive questions require a particular degree of legitimacy. How can this be achieved? Legitimacy is a multidimensional concept [91–93]. Interpersonal trust is part of that concept. In our context, procedural legitimacy plays an important role. To a considerable extent, it is the fairness of applied procedures, through which institutions receive the authority they exercise. This shapes procedural legitimacy and the willingness of people to cooperate with institutions, and to comply with the rules created by them. However, it is not only procedures that matter, but outcomes as well. For example, involving citizens fairly may not be sufficient to increase political support for the government [94]; outcome favorability might be less important, if more consensus-based procedures are used. Decisions about sensitive questions, in particular, might require more sophisticated voting methods than majority voting [83].

Transparency and accountability can be employed to acquire public support and establish trust in both technologies and governmental institutions (Fig. 6). In the context of digitally-assisted decision-making, attention to maintaining institutional trust is equally important. Trust depends on:

1. the knowledge of institutional norms shared between the truster and trustee (e.g., standards such as open source, non-proprietary software, a common language to define a problem, a possibility to participate in the definition of the problem);
2. the truster's knowledge of the motivation of the trustee (e.g. transparency about motivations and incentives);
3. professional role profiles combined with proper sanctions that render those in power accountable to the norms (regulations, rules, and laws) [95].

3. Participatory approaches to infrastructure planning and use

Though democracy is often considered to be primarily a governance system, it is tightly entangled with society, economy, and infrastructure use. Cities, in particular, are essentially for the people and by the people. However, the citizen's role in planning urban infrastructure and their use has been largely ignored until recently. Free and accessible spaces promote the open exchange of ideas between diverse people. Hence, sharing space should be supported, and urban planning decisions must consider higher citizen demands for inclusivity and fairness.

In this section, we focus on how the accessibility of spaces and the development of urban infrastructures can be digitally upgraded such that democratic values are supported. Moreover, we will elaborate on how considering citizen cognition and the semantics of urban elements (i.e., the fabric of an urban city) can create and provide more inclusive spaces and services.

[9] The Nash product, from cooperative game theory, finds a fair solution in bargaining situations. It is calculated as $NashProduct = \prod_i (U_i(b) - U_i(d))$, where $U_i(b)$ is player i's utility in the bargaining outcome, and $U_i(d)$ is their utility in the disagreement point.

Fig. 6. Illustration of how public support of and trust in technologies and government institutions (such as participation schemes and voting mechanisms) can be established by transparency and accountability.

3.1. Access

Democracies benefit from an open sharing of ideas, and a trustful atmosphere supporting socio-cultural exchange, which results from successful interactions among different kinds of interest groups and people. Shared space in the sense of a collective or public good is an important prerequisite for this [96]. It includes everything from public parks and plazas to public schools, universities, libraries, and more. Decades of research on inter-group bias [97] (has studied the behavioral attitudes of people towards group members and non-group members). The results suggest that an inclusive design of spaces can support the creation of in-group-sentiment (the feeling of belonging to a group). Thereby, it can promote participation and cooperation between people.

In view of this, we need to highlight a problematic trend: namely, the increasing tendency to restrict access to all sorts of spaces. Under such conditions, access becomes a privilege for a certain set of "authorized" persons. Such access restrictions are not necessarily based on good reasons or qualifications, but often on exclusive, competitive interests.

3.2. Adaptable services and infrastructures

Along with the ever-lasting technological progress, new services are continuously emerging and evolving. Adaptive services, which are becoming more common in cities around the world, address the limitations of a one-size-fits-all approach. They, thereby, mirror the main ideological tenets of democracies, which value personal freedoms. Adaptive services in smart cities can, for example, include adaptive traffic signal control [98], adaptive infrastructure use [99], adaptive reversible lanes [100].

Managing Complex Systems, whose behaviors are difficult to forecast, is one of the key challenges of modern societies. Urban traffic flows, for example, and many other complex dynamical systems are largely unpredictable—one can mainly make statistical statements. As a consequence, a top-down management of such systems, on the one hand, often falls short, as deviations from the predicted system behaviors occur. On the other hand, decentralized bottom-up approaches based on a flexible response to local short-term predictions often perform surprisingly well. Furthermore, by distributing decision-making processes, such bottom-up approaches can typically cope surprisingly well with local disruptions or failures, thereby preventing the entire system to fail. Such systemic resilience is highly desirable.

The example of adaptive traffic signal control showcases how the transition from centrally planned top-down solutions to adaptive bottom-up approaches based on real-time feedback can lead to significant improvements in the quality of services [101]. It is expected that these findings can also be extended to logistic systems, the world's economy, and democratic organization, as well as other complex systems contributing to modern societies.

Similar to adaptable services, adaptable infrastructures solution can address limitations of classical usage patterns, which have resulted from the functional segregation in the 20th century [102], often based on speed. This was mainly in favor of motorized vehicles [103], resulting in two adverse effects: First, their static design could not cope with rapidly changing spatial needs in the city [104]. Second, space allocation for motor vehicles was based on peak hours, while the restriction of alternative uses mostly extended over the entire day. In the future, when new intelligent technologies become available, adaptable infrastructures of interest, such as reversible lanes, laneless roads, or curbless flat streets, could automatically react to variable needs [105–107]. The integration of such autonomous elements, as well as their interaction with humans and each other, may become increasingly important [108–110] to facilitate coordination in complex situations [111–113].

We, therefore, believe a city should be able to respond to human activities and participatory needs by adaptable services, infrastructure, and streetscapes. Globally networked cities of the future should be locally adaptive, cooperative, and coordinated. To get there, one needs to develop

(1) effective technological means that can translate information and knowledge flows into the transformation and adaptation of physical space (e.g., adaptable services, flexible street uses), and
(2) informational frameworks and methods, which can handle complexity and diversity, such that they can constructively deal with the sometimes contradictory agencies and interactions in a pluralistic urban environment. For this, one needs a better understanding of how diverse flexible streetscapes are perceived, designed, operated, and accepted by people [114].

Altogether, the approach of adaptive infrastructures and services seeks inclusiveness in built environments and spatial planning, articulated by relational interactive data flows and software applications, which sense and react to changes in use, needs, and expectations [115]. This reappropriation of city-making by people and their direct intervention can be fostered by Open Source Urbanism [116,117]. Among others, this aims at co-creating infrastructures for democracy (new kinds of "commons"), which requires a higher degree of interoperability across different data and processes, including analysis, scenario planning, participation, monitoring and post-evaluation [118].

3.3. Semantic Urban Elements (SUEs)

The section above emphasizes why future cities need adaptable services and infrastructures for sustainable and resilient urban planning. In Fig. 7, we illustrate a conceptual framework highlighting how citizen participation and democracy by design can upgrade the built environment for citizen well-being, using semantics based on urban elements.

Semantic Urban Elements (SUEs) represent semantic information between urban elements, which is causally necessary to understand their relationship with each other and the resulting urban fabric. This virtue enables SUEs to represent urban elements as entities and relations, allowing for a mathematical representation and logical inference from complex urban data, as well as for computer-based applications.

Current research in urban design planning has focused mainly on extracting syntactic information from the "urban elements/resources" perspective. The critical problem of this is the lack of considering human cognition and perception of urban space. Typically, the role

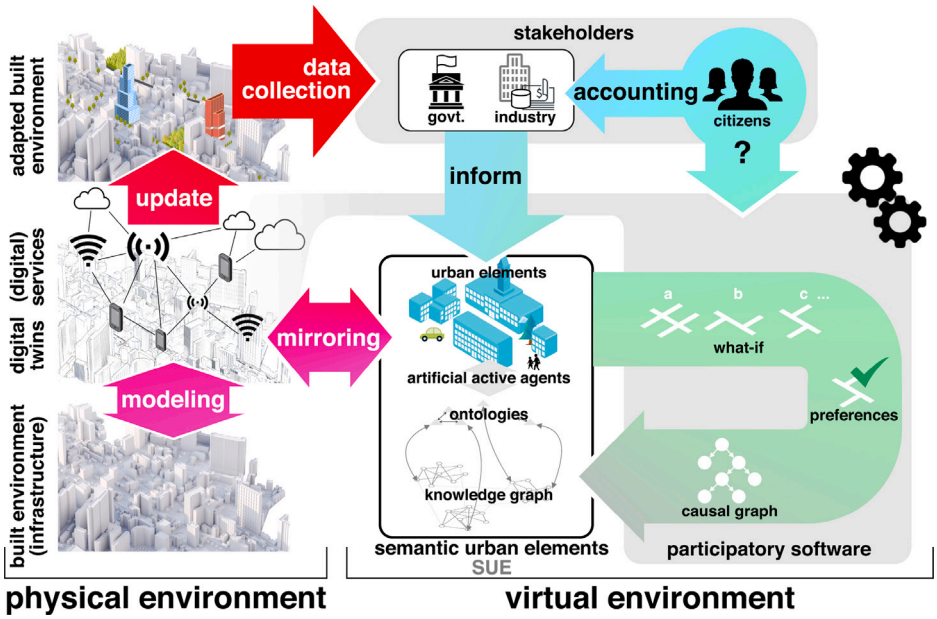

Fig. 7. Conceptual framework of Semantic Urban Elements for adaptable services and infrastructures based on citizen participation. The representation of the knowledge graph and Semantic Urban Element ontologies were inspired by [122].

of citizens in city planning has been restricted to consuming services from various cyber–physical systems. Recently, however, it has been stressed that the role of citizens should be extended from consumers to "prosumers" and contributors [119,120]. For example, they may provide feedback in terms of service ratings, be interaction partners of the system, or even take the role of an actuator implementing change. This brings us to the subject of co-creation and co-evolution discussed in Section 3.4.

Human-centric design of cities is critical to improving the quality of living. There are multiple solutions to this problem, but this paper focuses on participatory design approaches employing SUEs. The involvement of citizens in co-designing is essential. However, it is equally important to understand the implicit relationship between urban elements and the diverse sets of people interacting with them. For instance, the authors in Ref. [121] examine why the UK's public space failed to provide easy access to the city center for the elderly and differently-abled populations. Urban design often caters to average needs of citizens rather than the actual distribution of needs. Therefore, recent trends towards inclusive co-creation have to be further augmented by smart SUE technologies incorporating such relationships.

Typically, urban data does not follow a standard format and comes from different agencies such as the government, citizens, and private companies. To promote transparency and economic growth, SUE-based technologies will facilitate the integration of multiple data sources, thus, opening up new possibilities for urban representation, citizen participation, and the co-creation of urban design ideas. Moreover, the formal semantic representation of complex urban data can benefit machine processing and AI-based analysis.

3.4. Participatory approaches for open innovation

Traditionally, innovation has occurred within the confines of an organization. However, there has been a shift in recent years towards open innovation, which is the process of seeking ideas and solutions using more collaborative approaches. This shift has been influenced by a number of factors, including increased information availability, open-access hardware, software, and data, as well as the use of participatory approaches [123].

With the rapid technological advancements in recent years, digital tools have become an integral part of how key social actors communicate and interact with decision-makers. The benefits of such technologies are relevant for international relations and even extend beyond them, as these allow for new forms of societal and political participation. This is vital for effective diplomacy. For example, digital platforms enable the free flow of information and ideas, facilitating the exchange of knowledge and expertise [124]. In turn, this encourages collaborative innovation through participatory methods such as citizen science, co-creation workshops, hackathons, Governance Labs as well as other open-source and open-innovation initiatives [125,126]. They enhance alternative governance networks, such as across cities and connecting directly local communities around the globe which makes it possible to share globally local knowledge on common challenges [127]. Hence, local communities can lead innovation, share and scale it up in international diplomacy contexts [128]. The use of such methods allows organizations to tap into a wider pool of ideas and data, generating new solutions through collaboration, and ultimately supporting the goals of Computational Diplomacy.

In addition to the conventional frameworks and tools used for multi-stakeholder interaction, co-creation could also play an important role in facilitating democratic negotiations. By leveraging the diverse expertise and perspectives of stakeholders, co-creation can help generate innovative solutions that may not have been otherwise considered. The goal is for all stakeholders to share their ideas and knowledge in order to create something mutually beneficial—often something better than what any one side could have come up with by themselves [129,130]. Co-creation practices combined with technology-enabled platforms have profoundly changed democratic decision-making. Such methodologies can be used to benefit from the wisdom of the crowd at various stages of the democratic process.

Co-creation, in whatever form it takes, should have the following key elements:

1. *A common objective or purpose:* To be effective, co-creation must have a common goal or objective that everyone is working towards. This could be as simple as collaborating to develop a new product or service, or it could be more complex, such as collaborating to solve a societal problem or challenge.

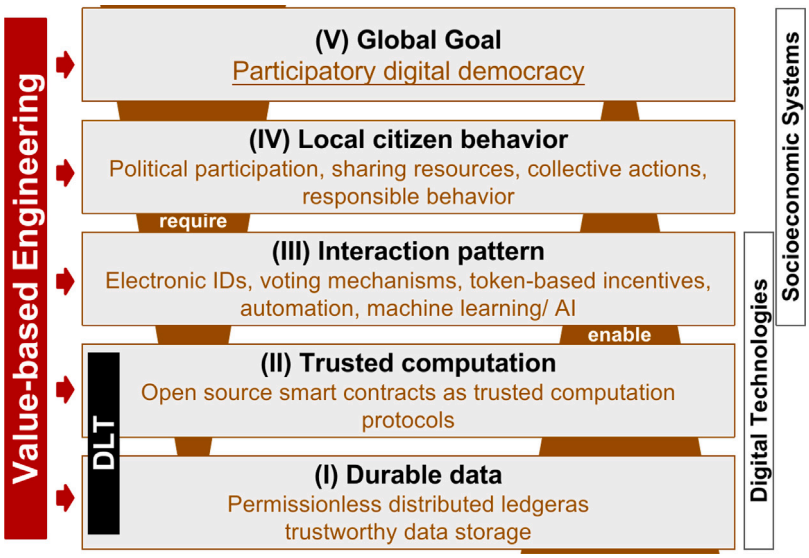

Fig. 8. Distributed ledger technology (DLT) infrastructure consisting of durable data (Layer I) and trusted computational protocols (Layer II), enabling the definition of interaction patterns (Layer III), which can assist citizen behavior (Layer IV) such that a participatory Digital Democracy emerges (Layer V) (illustration extended from [133,134]). Each of these layers can be instantiated by bottom-up self-organization such that socioeconomic systems emerge even when goals are diverse. Thus, a value-based engineering approach is required to guarantee that the resulting system aligns with the values of the affected people.

2. *Diverse perspectives:* When it comes to co-creation, different is not just ok or good; it is required. This is because different perspectives lead to different ideas, which can lead to innovative and effective solutions.
3. *A space for collaboration and innovation:* This refers to creating a room for people to come together and share ideas. That could be a physical space, such as an office or a workshop, or a virtual space, such as an online forum or chatroom. The important thing is to have a place, where people can feel at ease to collaborate and share ideas.
4. *Structures and processes to support co-creation:* This includes dedicating resources (people, time, money, etc.) to co-creation initiatives, as well as clearly defined roles and responsibilities for those involved. It also necessitates the establishment of mechanisms for ongoing communication and collaboration among stakeholders.

Digital technologies and participatory techniques have the potential to boost innovation and resilience by actively involving individuals and communities in the problem-solving processes [131]. People are more likely to engage into the process and be committed to the outcome, when they are actively involved in the design and implementation of solutions. Digital technologies can play an important role in data-informed decision-making [132] and the democratic transformation of society [10]. They can help to improve the quality of data available to decision-makers. For example, they can help collect data more accurately and efficiently, as well as process and analyze data more effectively. Furthermore, digital technologies can help to make data more accessible to decision-makers, allowing them to be better informed about the issues they face and the options available to them.

4. Distributed ledgers: Enabling technology for participatory digital democracies

A digitally upgraded democracy may leverage Distributed Ledger Technologies (DLTs) to ensure values such as transparency, trust and autonomy by design [135–138]. In particular, DLT can be an enabling technology for a participatory Digital Democracy with novel governance mechanisms [139,140], for example by facilitating durable data storage and trusted computations [133,134,141]. This is illustrated in Fig. 8: DLT allows for the implementation of smart contracts, which, in turn, enable the definition of various interaction patterns discussed in this work, such as voting mechanisms (Section 2.7), participatory budgeting (Section 2.5), Mchine Learning/AI (Section 5), or free information access 2.6. These interaction patterns steer local agent behavior, which can express itself in an increased political participation, sharing of resources, or responsible sustainable behavior. The product of these behaviors, when designed appropriately, can result in the global goal of a digital participatory democracy as illustrated in this work.

Nevertheless, the challenge is that each of these layers (see Fig. 8) enables socioeconomic systems with various properties, and the overall configuration space is large [142]. This makes the construction of a viable system difficult, requiring responsible engineering. On the one hand, a DLT could be constructed that optimizes for efficiency and control by restricting the access of the system to very few entities in the system, resulting in a closed and centralized system setup. On the other hand, utilizing the same technology, another DLT system can be configured in a "permissionless", democratic way, meaning that the public can participate in the securing and writing of data (also referred to as *consensus*), resulting in a participatory and secure system.

The interaction patterns as well (Layer III in Fig. 8) can be instantiated in opposite ways. For instance, electronic identities could be implemented with a top-down approach, requiring a centralized entity having signatory power, or they could be implemented in a bottom-up peer-to-peer manner, resulting in a paradigm referred to as self-sovereign identities, where individuals can create those identities in a self-determined way [143–146]. Both, however, do not address the question how to identify users or citizens, whether and when this is necessary, and what is appropriate. It also leaves the question unanswered, why one would track people rather than money and resources, which should be sufficient to achieve sustainability goals with less ethical issues.

Further complexity is faced when designing socioeconomic systems: mechanisms that appear to be decentralized, distributed and fair, may become more centralized over time [147] due to power concentrations in the underlying infrastructure layers (Layer I and II in Fig. 8). This could lead to computational protocols eventually being altered such that an originally fair interaction pattern might become unfair. So, the evolution of DLT systems over time is a non-trivial issue, requiring great attention and care in the design process. Nevertheless, the governance of a DLT is currently often neglected when design starts,

as technical considerations are typically more dominant [148]. Applying a value-based engineering methodology could support designers in instantiating governance mechanisms in DLT systems, which align with the values of the stakeholders, particularly the people affected, thereby potentially reducing the costs and complexity of mechanism implementation [148].

If set up well, a great benefit of DLTs is certainly that all participants can be treated equally and can be granted equal voting or economic rights in the system. Moreover, should DLTs be allowed to add a layer of trust between citizens, the burden of trustworthiness would be shifted from government and political rule to a digital infrastructure. Government bodies may then direct their attention towards creating DLTs that are sufficiently decentralized such that the conditions for the immutability and security of DLTs are ensured.

4.1. A circular and fair sharing economy through participatory sustainability

As we have discussed, DLTs can be constructed in multiple ways, which is one of their great strenghts [142]. This flexibility of DLTs allows them to be tailored for specific applications, and are very suited to value-centric design [133,138]. In particular, DLTs can also contribute to the co-creation and co-evolution of a more circular and fair sharing economy [149].

For example, DLTs could help to achieve sustainability goals by means of a participatory socio-ecological finance, incentive and coordination system such as **Finance 4.0** or **FIN4+** [150]. According to [133]:

> "Non-sustainability has be found to be one of the greatest challenges humanity is facing at the beginning of the 21st century [151]. In the past, it was tried to solve sustainability issues by means of laws and regulation [152]. By now, however, we can say it has not solved the world's problems on time [153]. We, therefore, need a new approach to tackle the challenge. Here, a bio-inspired approach [154] is proposed. Ecosystems are very impressive in terms of their logistics and recycling [155]. Nature has already managed to build something like a circular economy, i.e. closed cycles of material flows. It did not get there by regulation and optimization though, but by (co-)evolution—a principle, which is based on the self-organization of complex systems. Optimization, in contrast, which is often used in economics, tends to be based on a one-dimensional goal function and, therefore, to oversimplify the needs of complex systems. In particular, it often neglects other, non-aligned goals. Of course, there are also methods for multi-objective optimization [156], but co-evolution as we find it in nature seems to work differently, based on mutation, selection, and multiple feedback loops [157,158]. Using such principles underlying self-organization, complex systems may improve over time in a variety of aspects. A one-dimensional incentive system such as money cannot accomplish this task in the same way as multi-dimensional incentive systems can do".

Such an approach establishes a participatory approach to sustainability. Note that mobilizing citizens and civil society is expected to unleash a lot more transformational potential than if one would only rely on businesses and governments [123]. Given that finding sustainable solutions is an extremely pressing challenge, implementing a participatory sustainability approach, designed in a way compatible with Digital Democracy principles, is urgent.

5. Designing digital assistance for democracy by design

Decision-support systems will play a key role in future Digital Democracy initiatives and governance systems, as digital assistance becomes paramount in the decision-making of citizens and policymakers:

- *Automation*: The acquisition and processing of information for decision-making becomes more complex due to the scale, heterogeneity and variable quality of information. Automated and efficient approaches to structure, manage, analyze and learn from large amounts of data is required to support informed decisions.
- *Scaling up participation*: There is a political mandate to engage larger and more diverse groups in decision-making processes. This becomes evident from the low turnout rates in elections and various grassroot participatory initiatives such as citizen assemblies and Participatory Budgeting. Digital assistance can simplify participation, allowing distributed or remote individuals as well as diverse communities to raise a voice.
- *Decision complexity*: In a globally networked world, decisions in the public sphere are highly multi-faceted and often subject to controversies, misinformation and polarization. Guiding and supporting a more responsible, participatory and evidence-based decision-making with digital assistance is required to deal with this growing complexity of decision spaces.
- *Limited cognitive bandwidth*: Citizens may not be interested or able to get actively and directly involved in every single decision of the public sphere. Digital assistance is required to match a manageable number of interests, preferences and opinions, in order to manage the large numbers of specific decisions that affected citizens need to be able to trust.

However, introducing digital assistance comes with several risks that can undermine the democratic endeavor. Centralized management of data and computing operations may require trusted third parties that could result in information asymmetries and power imbalances. Big Tech is currently established on the basis of processing massive amounts of sensitive personal data. This opens Pandora's box for broad privacy violations, which in turn may lead to censorship, discrimination, manipulation, and loss of personal freedoms [159]. Therefore, it becomes of paramount importance how digital assistance and decision-support systems are designed to preserve democratic values and be resilient to misuses that can undermine the purpose, which they have initially been designed to serve. Therefore, a socially responsible design of digital assistance is a safeguard and important aspect of democracy by design.

5.1. Design based on human–machine hybrid collective intelligence

Democracy by design in digital societies is not viable without moving from mainstream AI to human–machine hybrid Collective Intelligence. This ambitious step requires adding a complex system design and novel functionality into decision-support systems in order to make sure that digital assistance does not erode democratic principles, but rather supports them. Fig. 9 presents an interactions model illustrating human–machine hybrid Collective Intelligence.

Here are some elements of our value-sensitive design framework:

1. Individuals autonomously self-determine parameters and alternative options to choose from as a contribution to operational flexibility. All personal data and preferences remain local, and sharing happens at an aggregate level, or with techniques such as differential privacy and homomorphic encryption [160].
2. Digital assistants coordinate among each other in order to support individuals in their decision-making. They efficiently carry out computational work that could not easily be carried out by the individuals themselves. For instance, deciding about a fair allocation of resources could be carried out at small scale within a citizen assembly. At large scale, digital assistants could solve multi-objective combinatorial optimization problems in a cooperative way, which would help citizen groups to discover possible new solutions to resource allocation problems in the public sphere. For instance, this could support participatory budgeting [90] and sharing economies [161]. Several decentralized

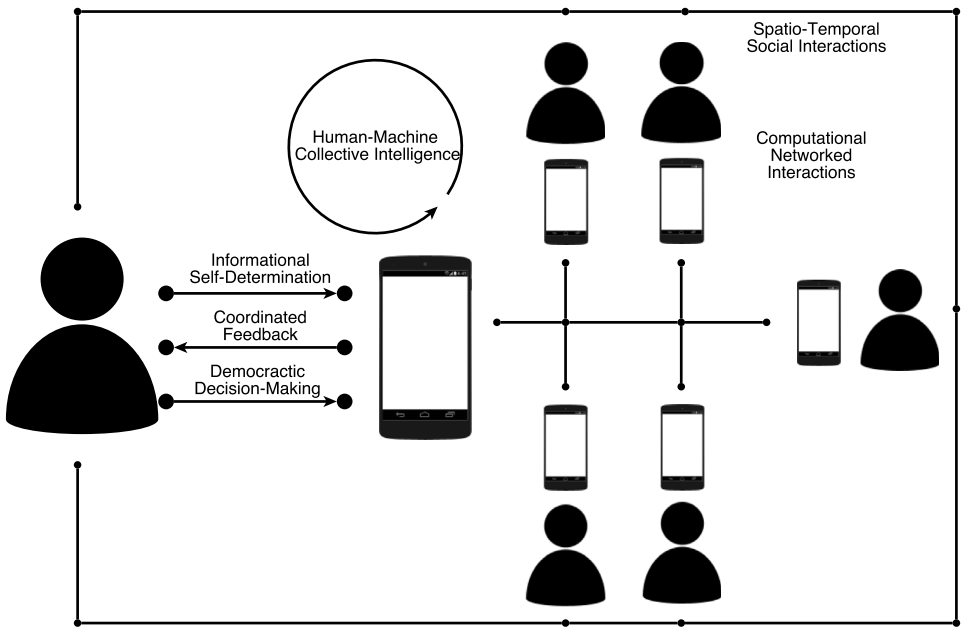

Fig. 9. Decision-support system design based on the concept of human–machine hybrid Collective Intelligence to empower democracy by design. Individuals self-determine the parameters and options of their personal digital assistants, which help taking better decisions and coordinating activities, while operating based on trustworthy, privacy-preserving and scalable decentralized computation (e.g. federated AI). They provide coordinated feedback that empowers citizens to make more democratic decisions.

algorithms could be applied in this context, for instance, collective learning [162], gossip-based learning [163], multi-agent reinforcement learning [164] and federated learning [165]. Such algorithms are trustworthy and resilient as they do not rely on single points of failure and they can enhance privacy.

3. Coordinated feedback by digital assistants can represent recommendations or rankings (based on personal values) among a number of discrete options to choose from. Individuals can align to this feedback by adopting one of the highly recommended choices. They can learn from this feedback, change their behavior intrinsically and even diffuse it in their social network, thereby building social capital. An example of this is learning to consume products more sustainably [166]. When consumers reject suggestions, this provides learning feedback to the digital assistants such that human–machine hybrid Collective Intelligence results from a co-evolutionary principle.

5.2. Digital assistance exemplars for democratic upgrade

In the following, we review the design features of several software exemplars with the purpose of demonstrating how value-based engineering can support democratic upgrades. Fig. 10 illustrates four software toolkits designed for seven democratic upgrades and ten value-based engineering principles.

Nervousnet[10] [16,169] is a general-purpose and open-source data management platform for pervasive devices such as smartphones. It is based on a data-driven application programming framework that collects, stores and composes physical and virtual sensor data on personal devices, without sharing them with third parties. End-users and developers have fine-grained control of what data are collected and how frequent sampling is performed. This makes it relevant for ubiquitous citizen engagement and participatory applications addressing informational self-determination via values such as privacy, autonomy, trust and legitimacy.

Smart Agora[11] [145,167] is a crowd-sensing and living-lab experimentation platform for indoor and outdoor environments using smartphones. It collects geolocated sensor, survey and voting data subject to users proving their witnessed presence and verifying conditions for more informed and evidence-based decision-making. Smart Agora turns every urban spot into a digital voting center, where citizens prove conditions for more informed decision-making. For instance, a Participatory Budgeting voter determines the preference for a project after digitally proving to be sufficiently informed about the different options. Using the Internet of Things [167] and blockchain technology [145], these proofs verify conditions such as the location of the voter (close to where the project will be implemented), or situational awareness (participation in local citizen assemblies). These democratic updates benefit both citizens and policy-makers. They support diversity, inclusion, and participation at a local level. They also improve decision quality, security, trust and legitimacy.

DIAS[12] [168,170,171] is a decentralized real-time data analytics service for large-scale networked users. Users of DIAS share with each other and in a peer-to-peer fashion privacy-enhanced summaries of local data. This allows each of them to compute locally almost any aggregation function such as summing up votes, the mean popularity of proposals in different communities or the top-k agenda priorities within a community. Using an advanced distributed memory system [168], estimates of aggregates can accurately adapt to actual values even when input values or the pool of users change dynamically. With informational self-determination in data sharing, resilience and decentralization in updating computations, DIAS supports inclusion, privacy, autonomy, participation, decision quality, trust and legitimacy, as depicted in Fig. 10.

EPOS[13] [161,162] is a collective learning algorithm for discrete choice multi-objective combinatorial optimization problems in the context of decentralized multi-agent systems. EPOS supports coordinated

[10] Available at https://github.com/nervousnet, https://github.com/ethz-coss/nervousnet-iOS.

[11] Available at https://github.com/epournaras/SmartAgoraDashboard, https://github.com/epournaras/SmartAgoraApp, https://epournaras.github.io/SmartAgoraDocumentation.

[12] Available at https://github.com/epournaras/DIAS.

[13] Available at http://github.com/epournaras/epos.

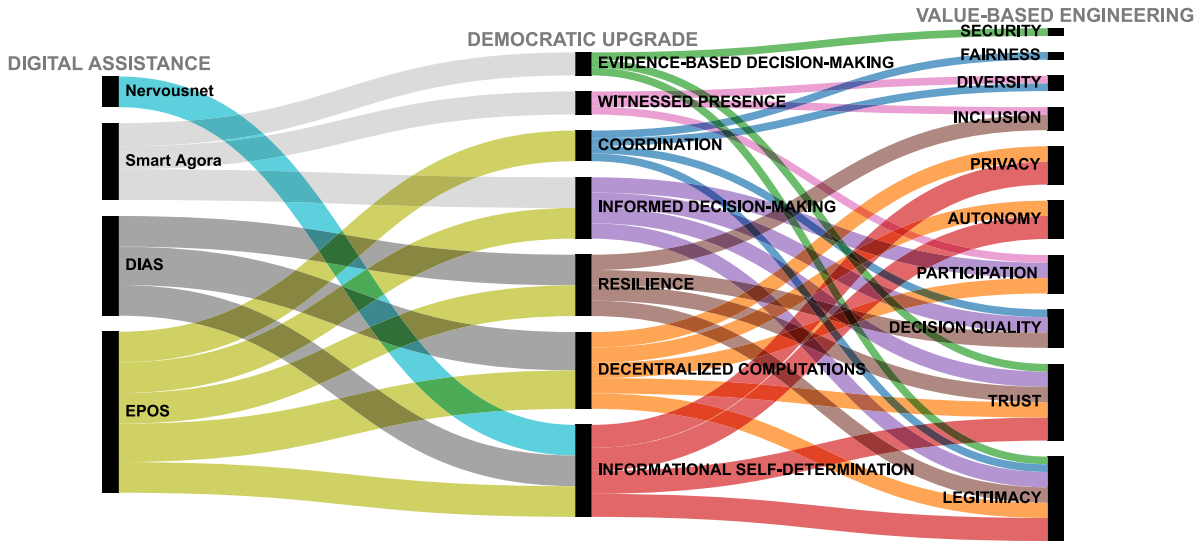

Fig. 10. Examples of four digital assistance toolkits that aim to demonstrate how a broad range of values can be enabled by novel functionalities that guide the democratic upgrade. (i) Nervousnet [16], (ii) Smart Agora [145,167], (iii) DIAS [168] and (iv) EPOS [162].

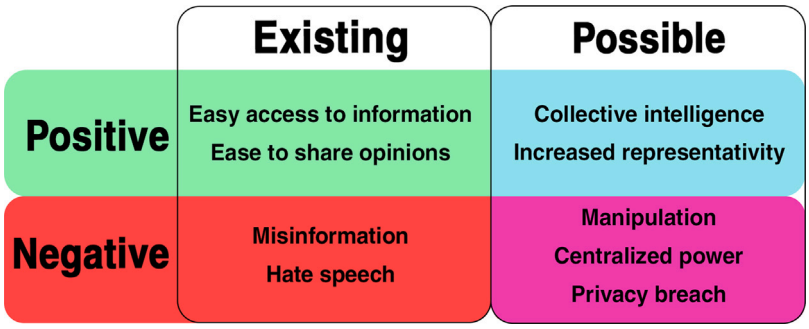

Fig. 11. Summary of positive and negative impact of digital tools on democracy. Particular attention should be given to the currently existing problems, while also looking at the future for new possibility and potential new dangers.

decision-making when agent choices among self-determined options are interdependent and their goals are modeled by non-linear cost functions. To solve such complex NP-hard optimization problems, agents self-organize for resilience in tree network topologies, over which they can efficiently perform iterative aggregation and intelligent decision-making. The optimization process addresses three classes of (opposing) agent goals: efficiency, comfort and fairness [162]. EPOS has been applied to a large spectrum of scheduling and resource allocation problems with balancing and matching objectives including: prosumer energy management, charging control of electric vehicles, load-balancing of bike sharing stations, traffic rerouting, edge-to-cloud load-balancing and other [161]. Via informational self-determination, coordination, informed decisions, resilience and decentralized computations, EPOS covers a large spectrum of values defined in Fig. 10.

These examples demonstrate the incremental growing complexity and interdisciplinary challenge of integrating engineering values in digital assistance for democratic updates. Further work is required to augment promising governance and participation platforms such as **Decidim** [172] with value-sensitive digital assistance. Other technologies such as distributed ledgers can also play a key role in improving trust and incentives for participation.

6. Discussion and conclusions

The world is undergoing a digital revolution. Rapid technological advancements are transforming the way we live, work, and communicate. The Internet, social media, cloud computing, and mobile technologies are just a few of the innovations that are transforming our world. This digital revolution also has a significant impact on how we govern our societies. A summary of the possible advantages and dangers of how these innovations can impact democracy is shown in Fig. 11. Overall it appears that we need a paradigm shift from

> a surveillance-based, data-driven, AI-controlled approach trying to "optimize" a society by targeting people

towards

> a measurement-enabled, data-oriented, AI-supported co-evolving society that is empowering people to innovate, coordinate, cooperate, and better contribute to the society of the future.

In fact, traditional top-down governance models are recently being challenged by new bottom-up, participatory approaches enabled by digital technologies. Planning and policy-making should be a continuous conversational process seeking for consensus or at least for the acceptance by the various involved parties, taking into account different meaning systems as well as bounded communication and cognition [173]. One of the most promising approaches to improving our societies is to use digital technologies that enable participatory governance. Such technologies are already empowering individuals and communities to have a direct say in decisions that affect them, resulting in more adaptable, responsive, trustable, and effective societies [129, 174].

In this paper, we have explained how digital tools can assist in the democratic upgrade of society by providing platforms for people to engage in dialogue and debate, by facilitating the exchange of information and ideas, by empowering individuals to take action, and by adopting technologies that can support value-based design. They can also help to improve government transparency and accountability, as well as increase citizen engagement in the democratic process. However, it is important to remember that digital tools are not a panacea for all ills. They need to be used in conjunction with other measures, such as public education, awareness-raising campaigns, and spatial planning to promote inclusion, spatial equity, and democracy.

While there are many challenges to be addressed, such as ensuring that all voices are heard and that everyone has access to digital tools, the potential for digital technologies to democratize society is great. With continued effort and engagement from all sectors of society, digital tools can certainly help to create a more innovative, participatory, and adaptive democracy.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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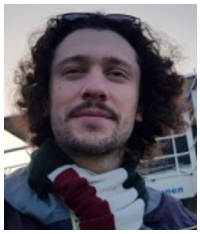

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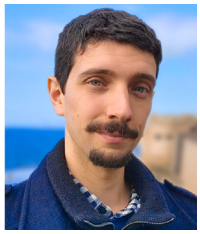

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