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 area called Computational Diplomacy. Our work focuses on a popular subarea of it. 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 in 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, and we make some recommendations for future research in this direction.

Keywords: Digital Democracy, Participation, Value-Based Engineering, Adaptive Infrastructure, Computational Diplomacy

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1. Introduction

Digital democracy refers to the use of digital technologies in the political sphere [1]. 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 [2] 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. Some of them are pretty different [3].

However, when discussing digital democracy, a few common themes stand out. These include using digital technologies to increase citizen participation in politics, make governance more accessible and transparent, and improve the efficiency of democratic institutions [4]. Digital means allow a higher level of participation [5, 6]. 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, trust and security. In view of pandemics, environmental destruction, financial instability, inflation, and broken supply chains, the world is currently in crisis. This applies to democratic and non-democratic countries alike.

To motivate our further discussion, we will start with a quote of Winston S. Churchill, who said on November 11, 1947:[1]

> "Many forms of Government have been tried, and will be tried in this world of sin and woe. No one pretends that democracy is perfect or all-wise. Indeed it has been said that democracy is the worst form of Government except for all those other forms that have been tried..."

Many people have believed the digital revolution would change this and 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

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[1]https://winstonchurchill.org/resources/quotes/the-worst-form-of-government/

of governance would be feasible, which would deliver better results. Here are a number of quotes exemplifying this:

In a TV contribution of "Titel Thesen Temperamente" on April 13, 2014,[2] Randolph Hencken famously said [translation into English]:

> "Democracy is an outdated technology. (...) It has brought wealth, health and happiness for billions of people all over the world. But now we want to try something new."

Larry Page of Google apparently saw things quite similarly, when he stated:[3]

> "I think as technologists we should have some safe places where we can try out some new things and figure out what is the effect on society, what's the effect on people, without having to deploy [them] into the normal world. And people [who] like those kind of things can go there and experience that, [but] we don't have mechanisms for that."

Peter Thiel as well seems to have a similar point of view:[4]

> "We are in a deadly race between politics and technology... The fate of our world may depend on the effort of a single person who ... makes the world safe for capitalism."

However, not only politics has been questioned: science has been challenged, too, namely, when Chris Anderson famously claimed[5]

> "The data deluge makes the scientific method obsolete."

All the recent quotes should, of course, be seen in the light of Big Data. Here, the state-of-the-art was famously summarized by CIA director Gus Hunt back in 2013:[6]

> "You're already a walking sensor platform," he said, and: "It is really very nearly within our grasp to be able to compute on all human generated information."

[2] entitled "Mikrogesellschaften. Hat die Demokratie ausgedient?" ["Micro-Societies: Is Democracy Outdated?"],
[3] https://www.businessinsider.com/google-ceo-larry-page-wants-a-place-for-experiments-2013-5
[4] `https://www.businessinsider.com/peter-thiel-is-trying-to-save-the-world-2016-12`
[5] `https://www.wired.com/2008/06/pb-theory/`
[6] `http://www.huffingtonpost.com/2013/03/20/cia-gus-hunt-big-data_n_2917842.html`

This data would be used to run societies in a cybernetic, data-driven way. Some ideas go so far as to create a post-choice, post-voting society [7]. Accordingly, in an increasingly automated society, everything would eventually be “decided” by algorithms [8]. Some experts, however, doubt that algorithms make decisions at all when compared to the way humans take decisions[7].

1.1. Previous Literature

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 [9, 10] 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 [11]. For this, we used a keyword search[8] 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 Figure 1, 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 equity, examining how new technologies can be used to empower marginalized groups [12], 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 [1, 3, 4, 13, 14, 15, 16, 17, 18]. 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

[7] `https://www.philomag.de/artikel/algorithmen-entscheiden-nichts`
[8] for “Digital Democracy” AND “Participat*”

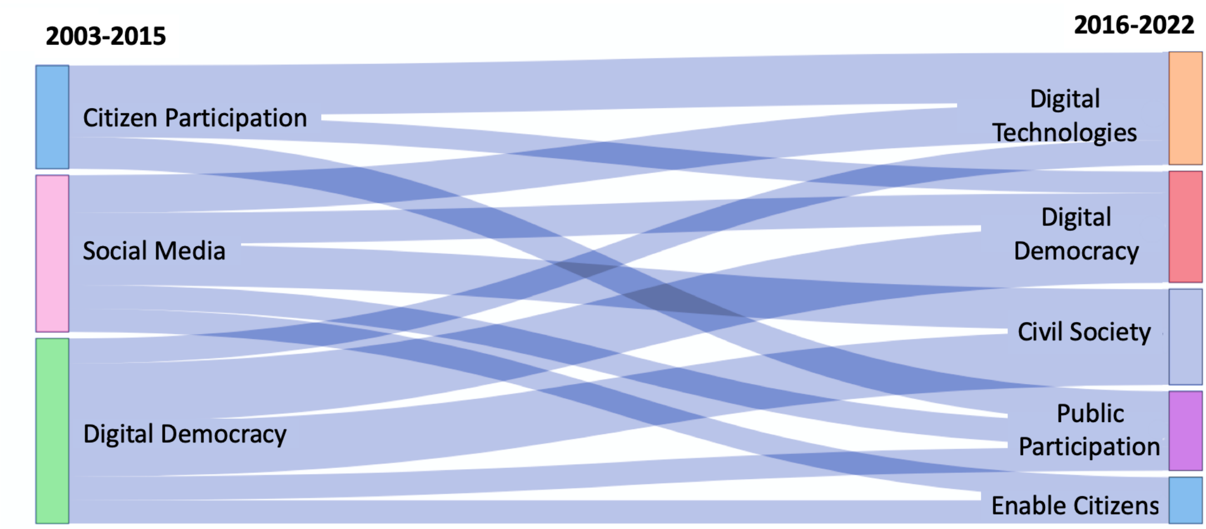

Figure 1: Thematic map showing the evolution of literature related to the subject areas of "digital democracy" and "participation".

political issues [19]. In the following, we will discuss a number of points that matter in this context.

1.2. Computational Diplomacy

Note that "Digital democracies" are one of the major fields of interest to the novel research area 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, inclusive, sustainable, and resilient society. Nevertheless, Computational Diplomacy will obviously (have to) care about other societal frameworks than democratic systems as well.[9] 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 (incl. lab/online experiments, and political or communication science approaches),
- the science of complex systems ("complexity science", incl. network science),

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

- 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 the roles of negotiation, incentives, and coalition formation, to mention just a few examples. Altogether, however, the methodological core is pretty similar.

1.3. Computational Social Science

Computational Social Science is a quickly expanding research area [20, 21, 22], 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 [9]. 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" [23] and "design for values" approach [24], also sometimes framed as "value-sensitive design" [25]. 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 [26]. However, people have started to considerably extend this approach beyond the subject of "privacy".

Recently, it has been demand that digital technologies should be built in ways, which promote "democracy by design". In this connection, it is relevant to ask what are the values underlying this approach. 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[10], calling for decentralization, separation of power (to prevent 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, 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" [9]. Despite its length, this list is certainly not complete, but still a good starting point for 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 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. Furthermore, we elaborate on how considering citizen cognition and their direct agency on components of the city from a semantic perspective. Hence, Semantic Urban Elements (SUE) can create and provide spaces and services for enhanced inclusivity and responsiveness to citizens' needs

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

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

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 recognized 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.

The freedom from fear is explicitly mentioned in the Preamble ("human beings shall enjoy 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. The "freedom of peaceful assembly and association" (Article 20) is thought to support this. The same principle should also be considered to apply online, particularly in Social Media.

In the digital age, all three of the above points call for improvements. For example, hate speech contradicts the "without fear" principle. Opinion manipulation, e.g. by means of (big) nudging or bots, undermines the second point [27]. Last but not least, limited access to relevant data and fake news undermine the first point. We also recognize the problems of filter bubbles, attention harvesting, and information asymmetries. This list could certainly further extended. The following paragraphs will address some of these issues in more detail.

2.2. Dealing with Mis- and Disinformation

Free and unbiased access to information is a prerequisite to (deliberative) democratic systems [28]. 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 [29, 30, 31]. By manipulating public opinion [32, 33], disinformation campaigns can serve to destabilize democratic systems. Such campaigns may spread on traditional as well as social media [34], where rapid dissemination is facilitated and multiplied by the high connectivity of digital environments [35].

Governments [36] and scientists explore ways to effectively counter wrong beliefs in disinformation online and its spread [37, 38, 39]. As shown in Table 1, approaches to counter disinformation may be passive, reactive, pre-active or proactive [34]. *Passive* approaches refrain from efforts to correct misinformation, so as not to increase its visibility and to prevent a backfire-effect [40].

Reactive approaches may take the shape of correcting mis- or disinformation with accurate information (usually called "debunking"). However, these corrections may not reach the original piece of disinformation, or they may even backfire by increasing trust in the false piece of information [41]. Reactive approaches undertaken by institutions may include swamping social media with more truthful articles to introduce counterviews [42], while social media providers introduce fact-checking and labelling, platforming or filtering. However, a restriction of information by private parties and private interests must be scrutinized for its impact on democratic procedures.

Prebunking is a *pre-active* approach grounded in inoculation theory [43], 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 analyse and identify new information. Education, digital literacy, and numeracy effectively are counter-indicators to belief in misinformation or conspiracy theories [44]. Trust in reliable media sources prevents the rejection of information by expert authorities [45].

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 engage online with different types of content, while mostly avoiding interacting with the other groups [46]. A similar observation is made for partisan political content or even scientific content. Therefore, promoting scientific content may sometimes even increase the divide between two groups, thereby undermining social cohesion [47]. Because of that, it is better to rely on methods such as digital literacy and digital enlightenment [48], allowing people to better *understand* news contents and their reliability, while *persuasion*-oriented methods may increase the divide in the population.

Besides the above discussed issues, one also needs to be aware of propaganda, mis- and disinformation using 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** [49]. Involving competent, elected community moderators would also be an option.

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

Table 1: The four main paradigms to combat misinformation.

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 [50, 51, 52, 53]. Hence, diversity should not be seen as a concession to individuals, but as a systemic benefit.

While socio-diversity should be protected 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[54]. Some interaction networks, such as degree-heterogeneous networks, obstruct behavioral diversity. Then, the population's diversity level is typically lower than if interactions were unstructured. Other interaction networks, such as highly clustered networks, favor behavioral diversity. Then, 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 the structural diversity index [54]. This index also suggests approaches to change interaction networks such that they sustain more diversity. For example, unfollowing extremely popular people, represented in networks by high-degree nodes, can promote diversity (see Figure 2).

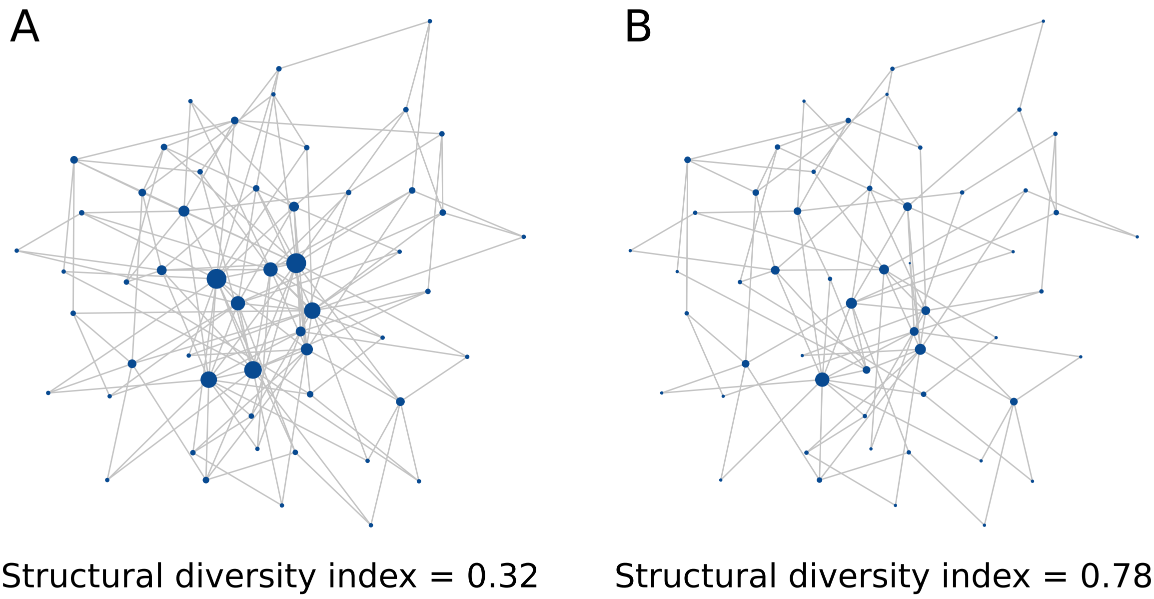

Figure 2: Behavioral diversity is promoted by removing links to highly connected individuals. If each individual in the network (A) removes the connection to his/hers most connected neighbor one obtains network (B). The transition from network (A) to network (B) entails a substantial improvement in the network's capacity to sustain diversity, which is quantified by an increase in the structural diversity index.

2.4. Finding Consensus

Political polarization is a major concern for modern democracies as it erodes social cohesion in favour of partisan interests [55]. This phenomenon can be so strong as to play a major role in the transformation of democracies into autocratic governance forms [56]. Indeed, in a polarized society in crisis, even people in favor of democracy are often willing to elect politicians not supporting democratic values, if they promise to support their interests.

While some may think that polarization can increase diversity and thereby benefit societies, it is actually the other way round. The term "polarization" is used to refer to cases in which people are divided over a subject or issue [56], whereas diversity means a distribution over many different dimensions (subject areas).

Increased polarization has been linked to more extreme opinions [57]. It also has some fundamental effects on peoples' feelings. Indeed, "affective polarization" refers to the dislike and angst between groups with opposite views [57].

An example often discussed in connection with polarization is the United States. Indeed, in recent years, it has been observed that polarization has constantly increased over there [58]. This resulted in the fact that democrats and republicans are becoming more and more divided while also liking each other less and less [59, 57]. This has reached a point where only 4% of couples are between democrats and republicans [60].

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 [61].

It seems that one obvious solution to this problem would be to apply methods fostering consensus. Going back to Edward Bernays, the author of the book "Propaganda", it is indeed possible to *engineer* public consent [62]. Despite its controversial uses in the past, the application of such methods is still common in the area of "Public Relations". In the meantime, they are also used in advertising and on Social Media platforms [63]. With the availability of personal data, it has even become possible to individualize these methods, as it is being done by "Big Nudging" [64]. This makes the engineering of consent a lot more effective, but it also creates opportunities to manipulate elections (see the Cambridge Analytica scandal) [65]). 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 thinking about deliberative elements that should be strengthened.

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[11] and its underlying system **Pol.is** [5]. The consensus-building platform allows citizens to set their own agenda for the conversation. Using upvotes and downvotes to each statement, it visualises real-time opinions using

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

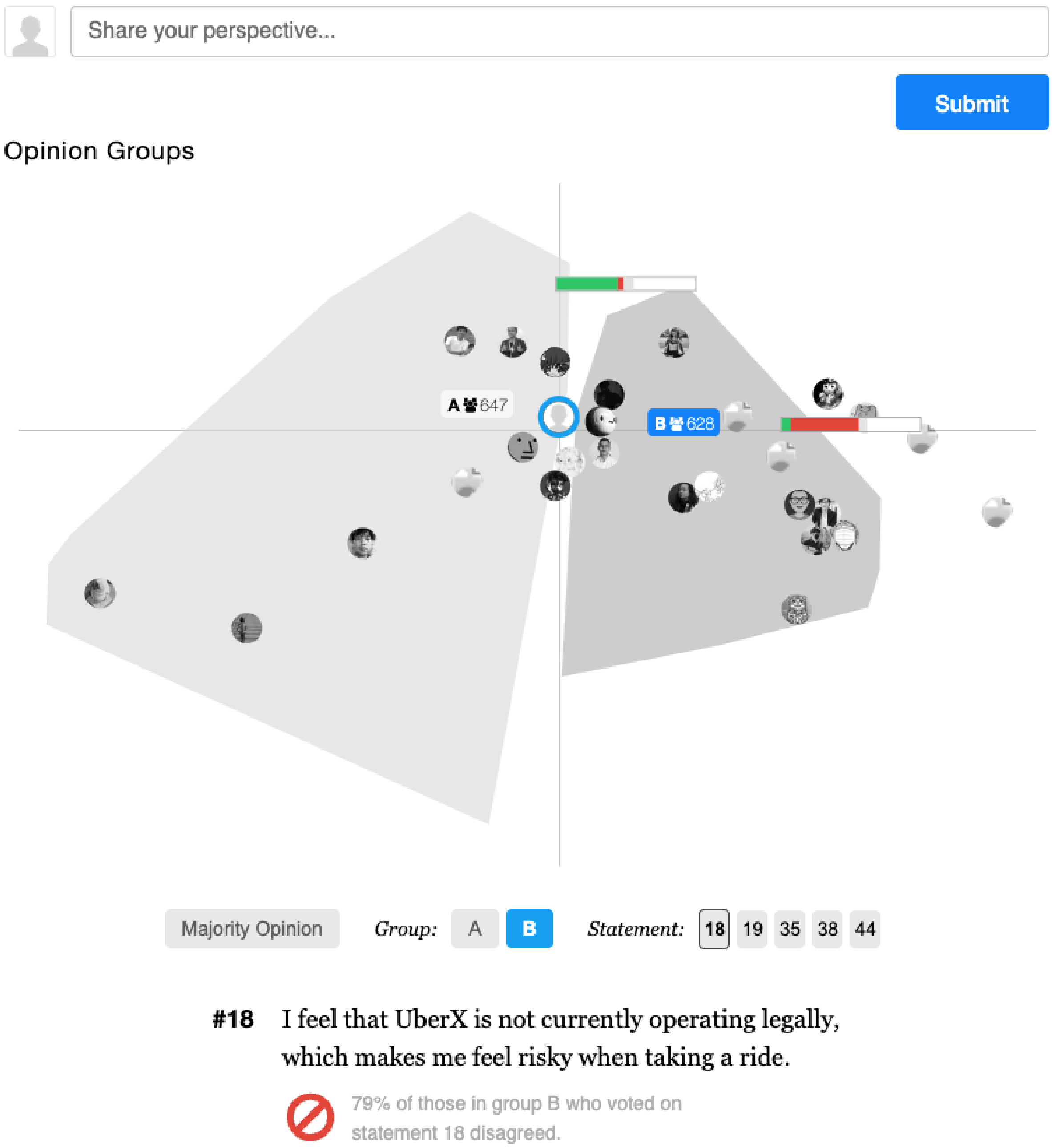

Figure 3: vTaiwan's use of Pol.is for the discussion of Uber regulation. Source: Screenshot from https://pol.is/3phdex2kjf.

PCA (Principal Component Analysis) and clusters people who voted similarly, using the k-means algorithm in a transparent manner.

As shown in Figure 3, like-minded groups emerge quickly on the opinion map, showing where the main consensus and disagreements actually lie. People then naturally try to come up with comments that will win votes from different groups, gradually overcoming the gaps. The platform gathers and analyses opinions, and then produces high-level, actionable, and statistically significant insights. Instead of initiating debates and prompting further polarisation, the process emphasises constructive co-creation across diverse opinions. 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.

2.5. (Digital) Participatory Budgeting

In order to engage citizens directly in political decision making, Participatory Budgeting (PB), a process that involves citizens allocating resources and monitoring public spending, has emerged as a democratic innovation [66] and a successful participatory instrument [67].

Participatory Budgeting has been used in many cities around the world. Since the emergence of Participatory Budgeting (PB) in the 1990s, it has helped to confront problems of political clienteles and social exclusion in Brazil, and has increased political legitimacy by having the budgetary process transparent, open, and public [68].

The standard process of most Participatory Budgeting programs follows the steps in collective intelligence (see Section 2.6), namely exploration, information exchange, integration of ideas, and finally, voting. This approach helps to address the fact that societies in the digital era are becoming more and more complex. Collective action is increasingly individualised and issue-driven, creating a new kind of “chaotic pluralism”, which is too dynamic and too complex to be addressed by traditional democratic processes or politics [69]. 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 digitalisation of Participatory Budgeting offers great opportunities for different stakeholders to partake in large-scale political decision-making processes in a more effective way [70]. According to the Participatory Budgeting World Atlas 2021 [71], Europe accounts for over half of the Participatory Budgeting initiatives worldwide, with over 5,000 schemes in 2019 alone. The past decade also has seen the rapid development of open-source citizen participation platforms such as Decidim [12] and Consul [13], which support large-scale collective intelligence.

Citizen participatory programs can be a useful tool for cities to identify real-time issues on the ground, and to channel more resources to disadvantaged groups and territories most in need [72]. These new digital tools are increasingly being used to reinforce citizen participation in an open culture, thereby strengthening democracy, and supporting cities and institutions to meet the demands for accountability and transparency [73, 74].

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" [75]. 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. One particularly interesting phenomenon of this kind is "collective intelligence" [76] (sometimes also called "the wisdom of crowds" [77]), which is a generalization of "swarm intelligence" [78].

"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.

[12] https://decidim.org/
[13] https://consulproject.org

The following procedure appears to be favorable for the emergence of "collective intelligence" [79]:

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 procedure is in line with insights into what enables successful deliberative public opinion formation processes [80, 3].

Digital tools can support all four phases listed above. Additionally, one may consider different voting methods. The best choice might depend on the problem to be addressed (see also the next subsection). Furthermore, the search for information and the exploration of the solution space may be promoted by suitable incentive systems [81].

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 [82], what biometric features they should use, and who should be responsible for managing the related platform(s) and data.

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

Not only in participatory budgeting contexts, but in democratic systems in general, the choice of the respective voting system is highly relevant for the decision-making process, its outcome, and the satisfaction with the result. It is especially important to avoid a "winner takes all effect, also know as the threat of "Tyranny of the Majority"[83], where one group basically dictates what is happening. The more diverse or complex the society becomes, the more important this might be.

For example, Quadratic Voting, proposed by Posner and Weyl [84] as a voting mechanism that aims to prevent this undesired situation of "Tyranny of the Majority" [83], has gained some traction for collective decision-making and blockchain governance [85]. Rather than ranking their choices, Quadratic Voting allows voters to express the intensity of their votes using voting credits. The cost of a decision is calculated as the square of the number of votes cast. By making the cost of choosing only one option expensive, the authors argues that Quadratic Voting have the effect of protects minority interests and discourages polarization. As diversity strengthens collective intelligence 2.6, voting innovations that ensure diverse outcome deserve some serious consideration.

A well-configured voting system should be able to support both, a participatory process and a fair outcome, which benefits a great majority of people affected:

1. *Input:* A proper participatory approach requires that voters can effectively express their preferences through *votes*.
2. *Output:* The applied *aggregation method* then determines a feasible allocation of resources, which can comprise diverse investments or solutions.

Both of the above-mentioned elements are theoretically well studied. However, for a successful implementation in practice, for example, in a participatory budgeting project, the user perspective needs to be taken into account.

In the following, we review both, input and aggregation methods, highlighting two sometimes contradictory properties: the theoretical characteristics and the user's perspective towards these.

When Participatory Budgeting settings are studied in the laboratory, in comparison to four other input methods participants appear to find k-approval the most straightforward to use. k-approval also outperforms every other input format in terms of consistency of votes and response time [86]. However, voters feel that k-approval is the worst in reflecting their preferences. From their perspective, *ranking by value* is the best.

This highlights that it is important to distinguish between what supports an efficient aggregation and what voters feel is essential when casting a vote [86]. Obviously, k-approval does not capture everything that matters for humans, such as their values. While efficiency is at the centre of a business or military approach, from a human-centric point of view, one should put a larger focus on what is valued by humans. Thinking, for example, of the important principle of division of power ("checks and balances"), democracies are not totally efficient *by design*. This is to protect humans, their interests, and their dignity. In order to enable solutions that are not just efficient, but also sophisticated, democracies use advanced technologies. For example, rather than implementing just solutions that those in power prefer, democracies benefit from engaging in a set of diverse solutions that satisfy as many people as possible. The latter allows the people to unfold their talents. In a society built on specialization and division of labor, this unleashes combinatorial benefits of diversity, which can contribute to a higher quality of life.

It is important to consider that, besides the input method, aggregation choice significantly affects a vote's outcome as well. A comparison of five *aggregation methods* within the context of a laboratory experiment [87] suggests the following:

1. Considering a bundle of projects chosen by the participants, maximizing the Nash product [88] appears to be the most appropriate method.
2. Based on the verbal explanations ranked by the participants, maximizing utilitarian social welfare is the aggregation method that seems to be most appropriate.

Hence, common majority voting is usually not the best method. Also note that an aggregation method, which ensures that at least one of the citizen's preferences is realised, increases the willingness of voters to participate [89].

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. Furthermore, decisions about sensitive questions require a particular legitimacy. How can this be achieved? Legitimacy is a multidimensional concept [90, 91, 92]. 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. Marien and Kern [93] emphasize that involving citizens (fairly) is not sufficient to increase political support for government. The outcomes of decision-making processes also are relevant. They speculate that outcome favorability might be less important if more consensus-based procedures are used. So, decisions about sensitive questions, in particular, might require more sophisticated voting methods than majority voting.

The illustration in Figure 4 shows how public support and trust in technologies and government institutions can be gained through transparency and accountability. In the context of digitally-assisted decision making, it is also important to care of institutional trust. This depends on:

1. the knowledge of institutional norms shared between truster and trustee (e.g., standards such as open source, non-proprietarian 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) [94].

3. Sharing Space, Infrastructures, Goods, and Services

Though democracy is often considered to be primarily a government system, it is tightly entangled with how society and the economy are organized. Therefore, it is also important to consider, how the non-political aspects of citizen lives are affected by and contribute to democracies and their values. In this section, we focus on the ways in which the use of spaces, infrastructures, goods and services can be digitally upgraded such that democratic values are supported. Moreover, we

Figure 4: 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.

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.

3.1. Access

Democracies live from an open exchange of ideas, and a trustful atmosphere supporting exchange, which results from interactions among different kinds of people and interest groups. Shared space in the sense of a collective or public good is an important prerequisite for this [95]. It includes everything from public parks and plazas to public schools, universities, libraries, and more. Decades of research on inter-group bias [96] (which compares the behavioural attitudes of people towards group members and non-group members) suggest, that an inclusion-centered design of spaces can support the creation of in-group-sentiment (the feeling of belonging to a group) and thereby promote participation and cooperation between persons.

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. This undermines the principles of inclusion and space equity [97], even though inclusion plays a major role in the Sustainable Development Goals (SDGs).

3.2. Adaptable Services and Infrastructures

Beyond the mere physical configuration, the shaping of our built environment encodes and encapsulates myriads of interactions, power relations, productive systems, and ideologies. Cities are simultaneously means of empowerment, but also of production and domination, which reflect and perpetuate a mode of development within an ideology and culture, which mediates politics between economic and social factors [98, 99, 100]. Along with the ever-lasting technological progress, new services are continuously emerging and evolving. Most of these new services are geared towards providing city-dwellers with easy access to the latest technologies.

Adaptive services, which are becoming more common in cities around the world, address the limitations of one-size-fits-all solutions. This approach mirrors the main ideological tenets of democracies, which treasure individuality and freedoms. For example, adaptive services in smart cities can include adaptive traffic signal control [101], adaptive infrastructure use [102], adaptive reversible lanes [103], etc.

Managing complex systems, whose behaviors are difficult to predict, are among 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 or fails, as deviations from the predicted system behavior occur. On the other hand, decentralised bottom-up approaches that are 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 [104]. 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.

Many adaptive services can either be implemented in a centralized or decentralized way [105]. Centralized services are often slightly more efficient and have clear ownership rules, while decentralized services are often characterized by co-ownership or distributed ownership, which can help to reduce instances of power abuse [9]. Adaptive mobility-sharing [106] is an innovative approach to transportation that is being piloted in a number of cities around the world. The concept is based on the sharing of resources (such as vehicles and infrastructure) between different users in order to improve efficiency and reduce costs. Such mobility-sharing services can be combined with Internet of Things technologies (IoT) to create additional benefits for the respective citizens. Examples relate to real-time air environmental monitoring [107], noise mapping [108], community-based health services, and much more. Services like these may adapt to individual users, giving them access to the data relevant for them rather than just to aggregates that are relevant on average. Such fine-grained data access enables better, data-based decisions [109, 110], without having to be based on targeting by another system or someone else.

Similar to adaptable services, adaptable infrastructures solution can address the limitations of a one-kind-fits-all approach. Typically, urban infrastructures do not reflect the diversity of needs of people relying on them. Indeed, many cityscapes and the rules that set urban space affordances [111], were established in the beginning of the 20th century.

In the past, for example, urban planners implemented a functional segregation in road networks based on speed. This was in favor of motorized vehicles [112], resulting in two adverse effects: First, their static design could not cope with rapidly changing needs of space in the city [113]. Second, space allocation for motor vehicles was based on peak hours, but the restriction of alternative uses of this space mostly extended over the entire day. In the future, autonomous vehicle traffic could help to overcome this shortcoming.

The rise of autonomous driving technologies allows one to imagine digitally upgraded urban infrastructures that can integrate high levels of traffic demand with a higher diversity of uses, while flexibly responding to changing mobility needs [114, 115]. Moreover, such layouts can be tested in advance using Virtual Reality technologies. Layouts of possible adaptable infrastructures of interest, such as reversible lanes, laneless roads, or curbless flat streets, would automatically react to city's needs [116, 117, 118]. The integration of such autonomous elements, as well as their interaction with humans and each other, is increasingly important [119, 120, 121], particularly as it may support coordination in complex situations [122, 123, 124].

We believe a city should be able to respond to human activity and participation by adaptable services, infrastructure, and streetscapes. This should enable a globally networked city to be locally adaptive, coordinated, and cooperative. 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 it can constructively deal with the sometimes contradicting agencies and interactions in a pluralistic urban environment. For this, one needs a better understanding of how diverse flexible streetscapes may be perceived, designed, operated, and accepted by people [125].

Altogether, the approach of adaptive infrastructures and services seeks for inclusiveness in built environments and spatial planning, articulated by relational interactive data flows and software applications, which sense and react to changes in uses, needs, and expectations [126]. The reappropiation of the process of city making by people and their direct intervention can be enabled by Open Source Urbanism [127, 128]. Among others, this aims at co-creating infrastructures for democracy (new kinds of "commons"), which requires a further development of interoperability across different data and process phases, including analysis, scenario planning, participation, monitoring and post-evaluation [129].

3.3. Semantic Urban Elements

The section above emphasizes why future cities need adaptable services and infrastructure for sustainable and resilient urban planning. In Figure 5, 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 that 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 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 [130, 131]. 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 Sec. 3.4.

Human-centric design of cities is critical to improve the quality of living. There are multiple solutions to this problem, but this paper focuses on the participatory design approach 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. [132] 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 citizens' average needs 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

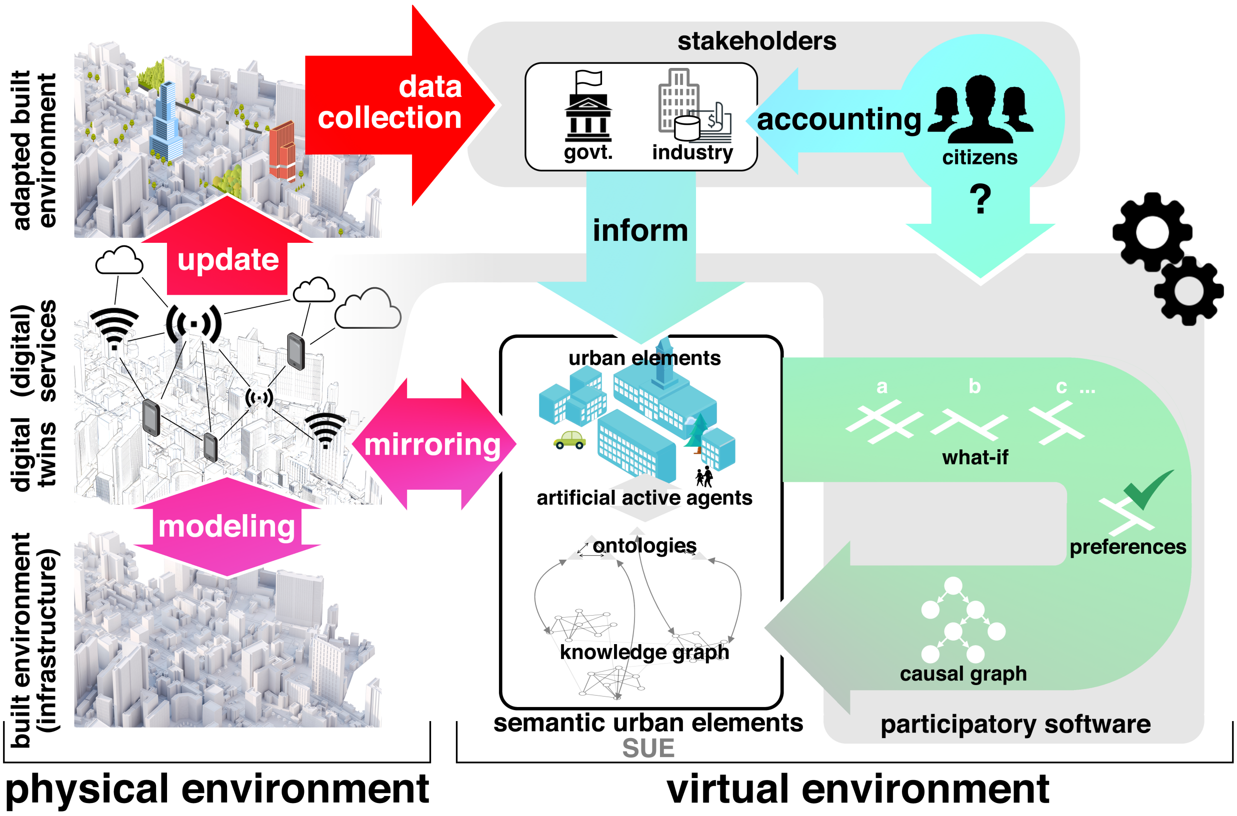

Figure 5: Conceptual framework of Semantic Urban Elements for adaptable services and infrastructures based on citizen participation. The representation of the knowledge graph and Semantic Urban Element ontologies were inspired by [133].

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.

SUE technology will benefit cities by generating diverse designs via participatory tools (see Sections 2 and 3). In scenarios of adaptable infrastructures, counterfactual queries can be made, using data from real-time sensors to adapt the configuration of urban elements to increase well-being, safety, sustainability, and resilience. Furthermore, SUE-based technology will facilitate conceptualizing citizen feedback about above-mentioned urban forms via participatory planning [134]. Citizen feedback will be analyzed, and semantic information about urban elements identified and presented to co-designers, decision-makers, or AI-based urban design tools. This will serve the goal of better, dynamic knowledge representation of essential building blocks of urban fabrics.

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 [135].

Technological advancements have made it easier for people to connect, collaborate, and work towards common goals. They have helped to connect people and communities, and have given rise to new forms of social and political participation. Digital technologies have also enabled the development of new platforms for expression and exchange, which has facilitated the free flow of information and ideas, cooperation and collective intelligence [136]. Therefore, organizations are using new ways of innovation that are based on participatory methods such as citizen science, co-creation workshops, hackathons, etc. These methods allow organizations to tap into a wider pool of ideas and open-source data and technologies to generate new solutions through collaboration [137].

Citizen science is an open, participatory approach to scientific research. It is a type of crowd sourcing that uses the input of communities to contribute to scientific research. The participatory approach in citizen science is a way for citizens to be actively involved in the process of problem formulation, data collection and analysis [107, 138]. This means that they are not simply passive observers, but instead active participants in the process. The concept of co-creation has been widely used in Citizen Science activities. Co-creation is a process in which groups and/or individuals work together to develop ideas, solutions, and even services, rather than separately. 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 [139, 140].

Co-creation practices combined with technology-enabled platforms have profoundly changed democratic decision-making. Such methodologies can be used to tap into the wisdom of the crowd at various stages of the democratic process. There are various approaches to co-create, but some of the most common are open innovation challenges, hackathons, design sprints, and co-creation workshops.

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 toward. 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.
2. *Diverse perspectives:* When it comes to co-creation, different isn't just ok or good; it's 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. This 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 that it is 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 [141]. 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 [142] and the democratic transformation of society [9]. 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 analyse 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: An Enabling Technology for Participatory Digital Democracies

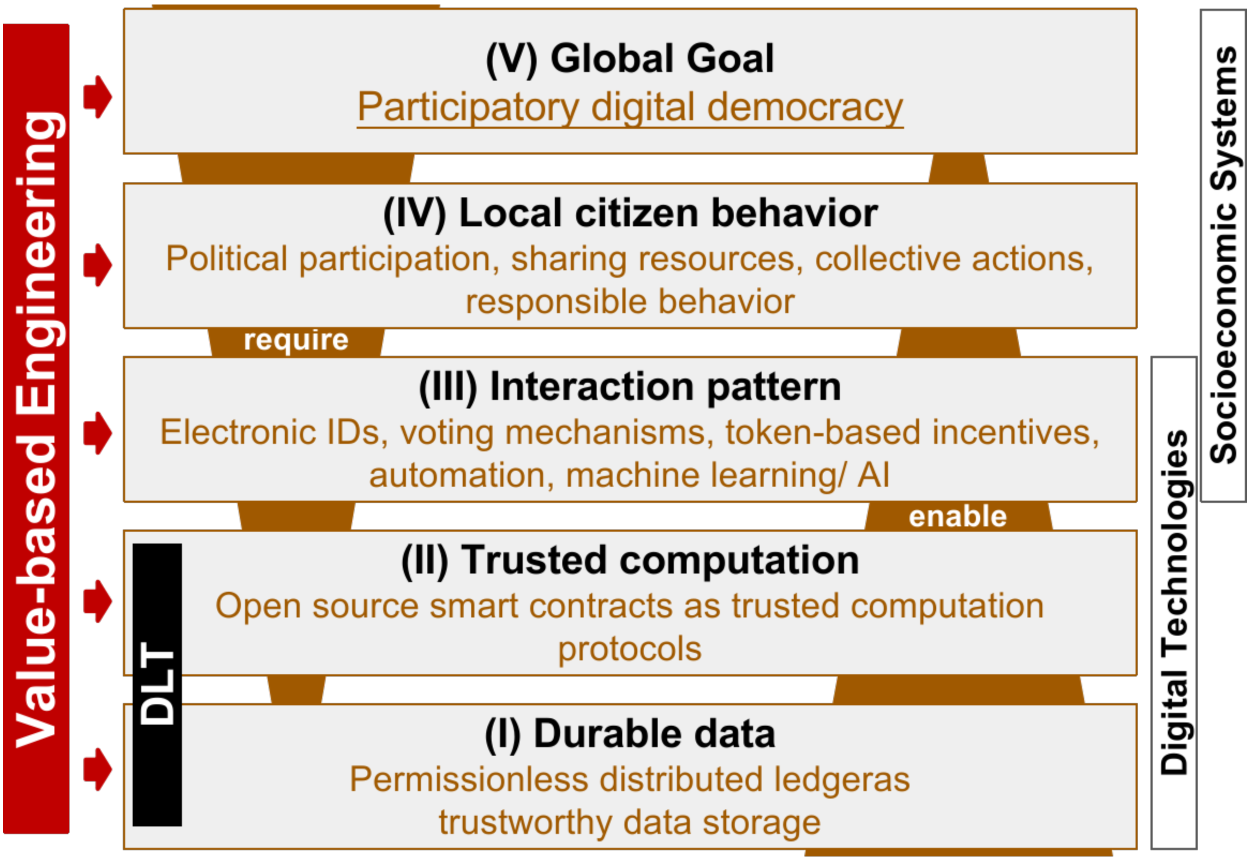

Figure 6: Distributed ledger technology (DLT) infrastructure consisting of durable data (Layer I) and trusted computational protocols (Layer II), enabling the definition of interaction patterns (Layer III), which can assist citizen behavior (Layer IV) such that a participatory digital democracy emerges (Layer V) (illustration extended from [143, 144]). 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.

A digitally upgraded democracy may leverage Distributed Ledger Technologies (DLTs) to ensure values such as transparency, trust and autonomy by design [145, 146, 147, 148]. In particular, DLT can be an enabling technology for a participatory digital democracy with novel governance mechanisms [149, 150], for example by facilitating durable data storage and trusted computations [143, 144, 151]. This is illustrated in Figure 6: 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), machine 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 (Figure 6) enables socioeconomic systems with various properties. This makes the construction of a viable system difficult, requiring responsible engineering. Given its large configuration space [152], on the one hand, a DLT system can be configured such that it is "permissionless", meaning that the public can participate in the writing (also referred to as *consensus*) and the securing of data, resulting in a system that is very inclusive and secure. On the other hand, utilizing the same technology, another 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 [152].

Also the interaction patterns (Layer III in Figure 6) 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 [153, 154, 155, 156]. Both, however, does 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 [157] due to power concentrations in the underlying infrastructure layers (Layer I and II in Figure 6). 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 [158]. 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 cost and complexity of mechanism implementation [158].

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, Distributed Ledger Technologies can be constructed in multiple ways, which is one of their great strenghts [152]. This flexibility of DLTs allows them to be tailored for specific applications, and are very suited to value-centric design [143, 148]. In particular, DLTs can also contribute to the co-creation and co-evolution of a more circular and fair sharing economy [159].

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+** [160]. According to [143]:

> "Non-sustainability has be found to be one of the greatest challenges humanity is facing at the beginning of the 21st century [161]. In the past, it was tried to solve sustainability issues by means of laws and regulation [162]. By now, however, we can say it has not solved the world's problems on time [163]. We, therefore, need a new approach to tackle the challenge. Here, a bio-inspired approach [164] is proposed. Ecosystems are very impressive in terms of their logistics and recycling [165]. 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 optimisation though, but by (co-)evolution—a

principle, which is based on the self-organisation of complex systems. Optimisation, 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 [166], but co-evolution as we find it in nature seems to work differently, based on mutation, selection, and multiple feedback loops [167, 168]. 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 [135]. 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 policy-makers:

- *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 participation 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, inclusive 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 a massive amount 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 [169]. 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. Figure 7 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,

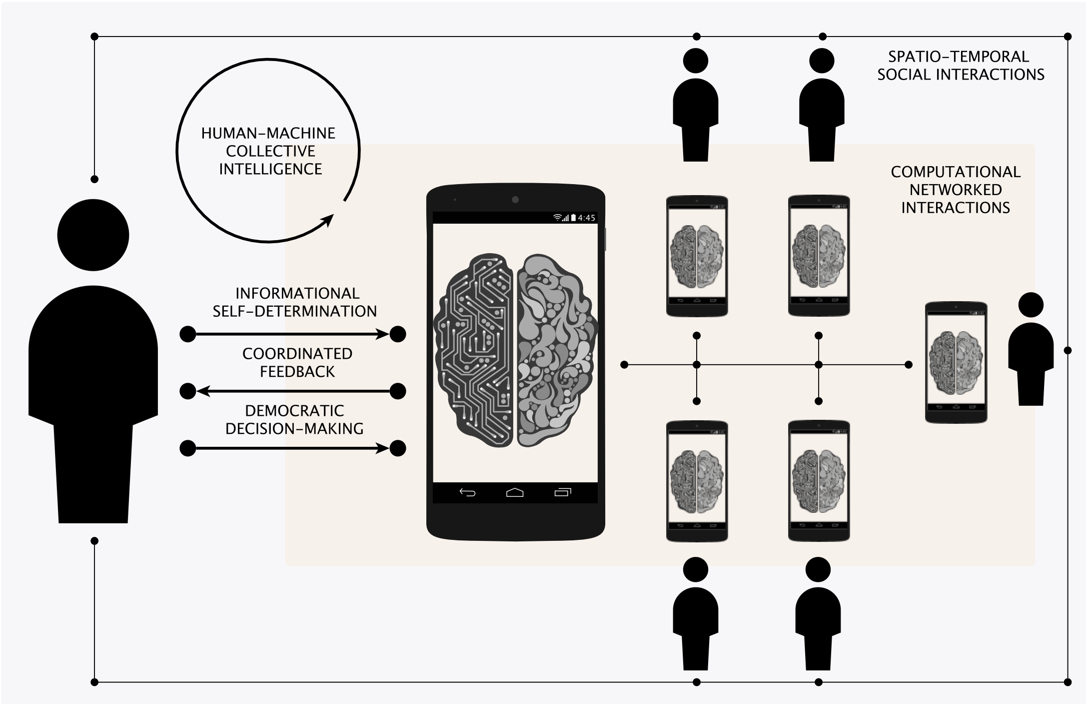

Figure 7: Decision-support system design based on the concept of human-machine hybrid collective intelligence to empower democracy by design. Individuals self-determine the parameters and options of their personal digital assistants, which help taking better decisions and coordinating activities, while 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.

and sharing happens at an aggregate level, or with techniques such as differential privacy and homomorphic encryption [170].

2. Digital assistants coordinate among each other in order to support individuals in their decision-making. They carry out computational work efficiently that could not easily be carried out directly by individuals. 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 [89] and sharing economies [171]. Several decentralized algorithms could be applied in this context, for instance, collective learning [172], gossip-based learning [173], multi-agent reinforcement learning [174] and federated learning [175]. 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 [176]. 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. Figure 8 illustrates four software toolkits designed for seven democratic upgrades and ten value-based engineering principles.

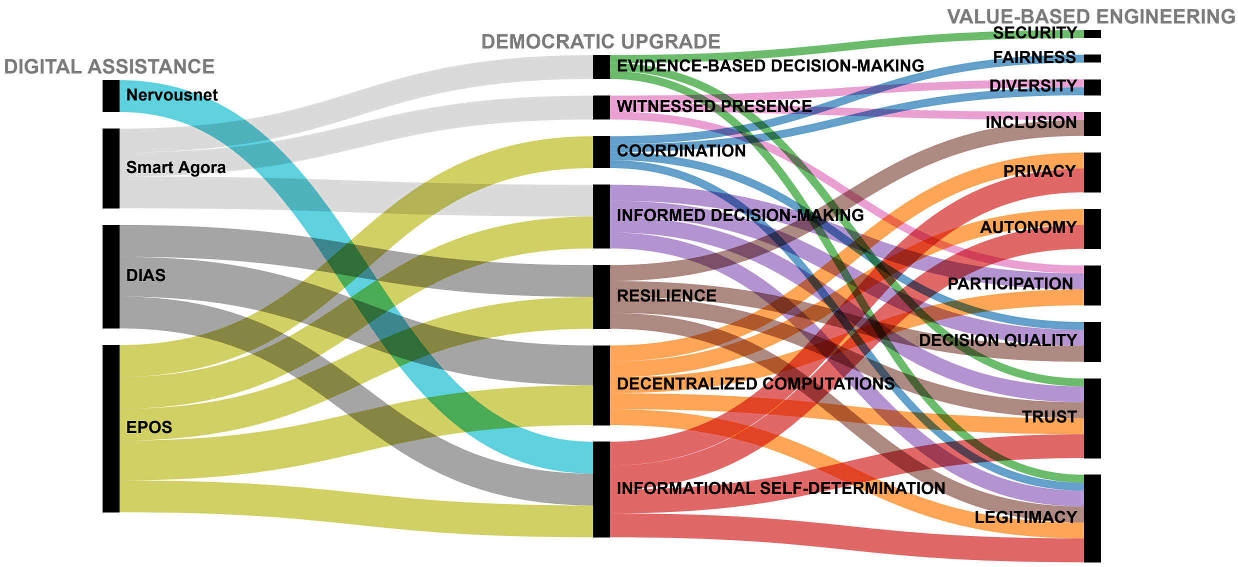

Figure 8: Examples of four digital assistance toolkits that aim to demonstrate how a broad range of values can be enabled by novel functionalities that guide the democratic upgrade. (i) Nervousnet [15], (ii) Smart Agora [155, 177], (iii) DIAS [178] and (iv) EPOS [172].

Nervousnet[14] [15, 179] is a general-purpose and open-source data management platform for pervasive devices such as smart phones. 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 participation applications addressing informational self-determination via values such as privacy, autonomy, trust and legitimacy.

Smart Agora[15] [177, 155] 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 a more informed and evidenced-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 [177] and blockchain technology [155], 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[16] [178, 180, 181] 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 [178], 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

[14]available at `https://github.com/nervousnet`,`https://github.com/ethz-coss/nervousnet-iOS`

[15]available at `https://github.com/epournaras/SmartAgoraDashboard`, `https://github.com/epournaras/SmartAgoraApp`, `https://epournaras.github.io/SmartAgoraDocumentation`

[16]available at `https://github.com/epournaras/DIAS`

decentralization in updating computations, DIAS supports inclusion, privacy, autonomy, participation, decision-quality, trust and legitimacy, as depicted in Figure 8.

EPOS[17] [172, 171] is a collective learning algorithm for discrete choice multi-objective combinatorial optimization problems in the context of decentralized multi-agent systems. EPOS supports coordinated decision-making when agent choices among self-determined options are inter-dependent 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 [172]. 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 [171]. Via informational self-determination, coordination, informed decisions, resilience and decentralized computations, EPOS covers a large spectrum of values defined in Figure 8.

These examples demonstrate the incremental growing complexity and inter-disciplinary 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** [182] with value-sensitive digital assistance. Other technologies such 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 Figure 9. Overall it appears we need a paradigm shift from

[17] available at `http://github.com/epournaras/epos`

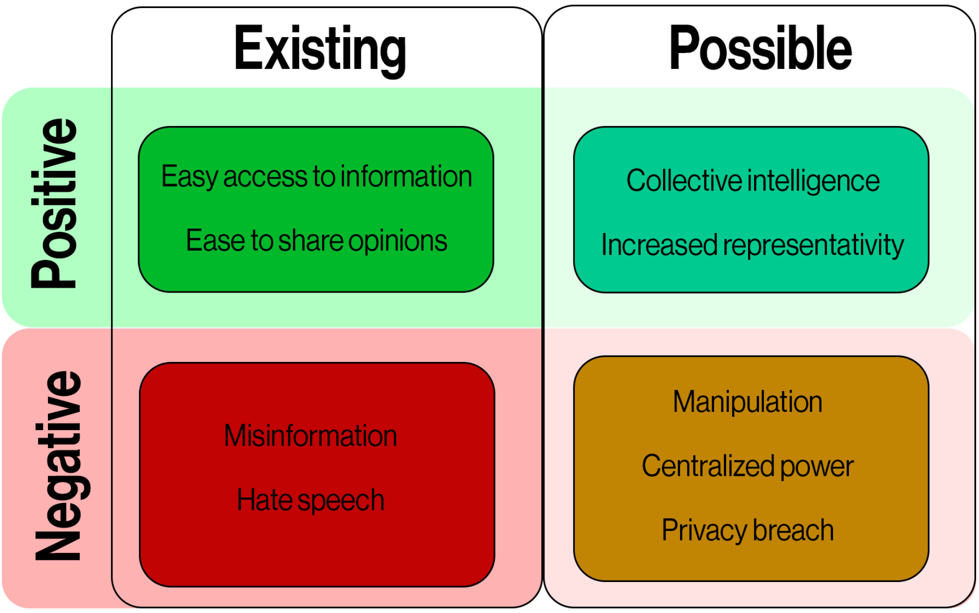

Figure 9: Summary of positive and negative impact of digital tools on democracy. Particular attention should be given to the currently existing problems while also looking at the future for new possibility and potential new dangers.

> 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 contribute better 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 [183]. 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, trustable, responsive and effective societies [139, 184].

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 that promotes inclusion and spatial equity to truly improve 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 help to create a more inclusive, participatory, and responsive democracy.

Author Contributions

DH has proposed the concept of the paper and assembled the author team. He has also contributed to the writing of most sections and much of the underlying research reported. SM co-organized, structured, edited, and proofread the paper. He contributed to the writing of the Abstract, Sections 1, 1.1, 1.5, 3.4,1 and 6. MCB wrote section 4 and proof-read other sections. RH contributed to the writing of parts on legitimacy, transparency, and trust, and provided feedback to the paper (esp. part 1 and 2), and its structure. AM contributed subsection 2.3 and Figure 2. CIH contributed to the writing of the initial draft and contributed to improving the writing of advanced versions for the subsection "dealing with mis- and disinformation" and subsection "voting systems". She integrated those subsections into the red thread of the paper. Furthermore, she contributed to spelling and grammar checking. EP has carried out and contributed to a large body of the reported research. He contributed the section on digital assistance and decision-support systems. He has also edited and proofread this paper. DC contributed to subsections 2.2 2.4 and figure 9. RKD contributed to the writing of Section 3. Specifically, subsections 3.2 and 3.3. RKD also contributed to the initial drafting and conceptualizing of Figure 5. JASV contributed to the conceptualization and writing of Section 3 and particularly subsection 3.2 as well as to final design of Figure 5. MK contributed to conceptualizing and writing the subsection 3.2. ES contributed to the subsection 2.2 in content and form. JY contributed to the writing of section on 2.4, 2.7 and 2.5. CC contributed to the writing of section 3 and proofreading of the document.

All authors contributed to the manuscript and approved it.

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