



Peer Community In Network Science

Bio-inspired solutions for collective decision-making in a networked society

Frédéric Amblard based on peer reviews by **Camelia Florela Voinea** and 1 anonymous reviewer

Cédric Sueur, Christophe Bousquet, Romain Espinosa and Jean-Louis Deneubourg (2021) Improving human collective decision-making through animal and artificial intelligence. Missing preprint_server, ver. Missing article_version, peer-reviewed and recommended by Peer Community in Network Science.

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Formal voting biases and weaknesses like Arrow's or Condorcet's paradoxes are known for quite a long time, but they are often considered as curiosities for mathematicians and cases that rarely occur in practice. Although, recent elections underlined the actual weaknesses of our collective decision-making processes, either concerning the resulting lack of representativity (people getting elected but representing actually a minority of the population) or more globally the efficiency of the decisions taken. A significant gap exists in between on one hand the opinions of a networked population that are structured and evolve using social media, leading to a much more visible diversity and on the other hand the ones of representatives that are still structured by political parties. Such a situation leads to questioning the processes used to choose representatives and more globally to make collective decision-making with alternatives that are proposed more and more (liquid democracy for instance (Blum and Zuber, 2016)).

The article by Sueur et al. shed new light on the situation by proposing to examine further the solutions selected along time by the animal kingdom in order to make collective decision-making. Although they advocate that the decisions taken are not the same (decision for an animal group to move to another place) and do not involve the same cognitive abilities at the individual level, the existing processes could get adapted to human contexts. One of the most striking advantages of such bio-inspired approach is that animal collective decision-making processes are robust and enable to manage conflicting views, diversity of opinions and avoid forms of despotism that are not much present in animals, rather consensual decision-making being the norm. Another argument, probably less put forward by the authors is that such solutions may scale well with large networked populations as they exist for some animal species. Therefore it looks like we could have a kind of

readymade library of processes for collective decision-making that are yet efficient to make timely decisions for different purposes with different population sizes and structures.

Their argument is consolidated by the possibility of using AI technologies in order to enable to support the adaptation of such solutions. Without building explicitly the link, they identify that AI could be used in order to guarantee a fair process and to scale up the proposed solutions at the level of massive populations.

This is probably the less convincing part of the proposal and it concerns the relation between human and AI. Even if the authors admit that the acceptance of AI solutions by part of the population is a key issue, as it concerns directly the legitimacy of the process and the compliance of the population with the resulting decision. They tend to minimize the gap to fill before having a fair AI with potential behavior that can be verified before using it with confidence to support a democratic process of decision-making.

Nevertheless, the article brings forward good arguments, well formalized using relevant concepts for the use of bio-inspired solutions for collective decision-making.

References:

Blum C, Zuber CI (2016) Liquid Democracy: Potentials, Problems, and Perspectives. *Journal of Political Philosophy*, 24, 162-182. <https://doi.org/10.1111/jopp.12065>

Sueur C, Bousquet C, Espinosa R, Deneubourg J-L (2021) Improving human collective decision-making through animal and artificial intelligence. hal-03299087, ver. 3 recommended and peer-reviewed by Peer Community in Network Science. <https://hal.archives-ouvertes.fr/hal-03299087>

Reviews

Evaluation round #1

DOI or URL of the preprint: <https://hal.archives-ouvertes.fr/hal-03299087>

Version of the preprint: 1

Authors' reply, 24 July 2021

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Decision by [Frédéric Amblard](#), posted 08 June 2021

Interesting first version that would need revision in order to strengthen the arguments

The proposed article is very interesting in pointing the potential interest of nature-inspired design as a source of inspiration for collective decision-making. The drawbacks of the majoritarian voting system are well identified in the literature and several disciplines, artificial intelligence in particular, are searching for mechanisms that would enable to obtain collective decisions that better represent the actual individual opinion of the population. The participation of ethology to this issue and debate is more than welcome and the actual contribution would definitely deserve attention.

Despite the very positive global aim of the paper, several issues, underlined by the recommenders would enable, I think, to improve the quality of the contribution. A first important aspect concerns the readership. If, as I think, the intended audience is rather pluridisciplinary, the authors should take care to clarify concepts (efficiency of a collective decision-making, representativity, eventually coming from moral and political philosophy, as J.Rawls...) and provide more details about the examples given. The presentation of a kind of synthetic

scheme concerning collective decision-making in animal societies could also help in this perspective. Another important set of remarks concerns the risk of a direct transition from animal decision-making to human ones, in this perspective it would be important to position clearly the potential contributions and limitations of existing decision-making mechanisms and the particularities of human-being to integrate before than envisaging such solutions.

To summarize in few words, the proposed article has a great potential but would need some efforts of presentation at some point.

Reviewed by anonymous reviewer 1, 17 May 2021

Improving voting systems through animal and artificial intelligence: Review

Overall, I enjoyed reading this pre-print and learned plenty of interesting information from it. My expertise is from the animal behaviour side and so I have no expertise in the political science literature also reviewed here (I have already discussed this with the recommender/editor). I do feel though at the moment that the article would benefit from identifying specific similarities/differences and/or more tangible lessons to be learned (or not learned) than is currently the case, and to consider more of the caveats and key considerations when comparing animal collective behaviour and human political systems. Currently, this is a major limitation as I'm not quite sure what I am meant to take away from the paper other than that there are some similarities and differences. To this end, I also think providing a clearer and much more clearly sign-posted structure to the article would be helpful in achieving this. I have included my line-by-line comments below that came up as reading through, some were answer to some extent later on, but this would be resolved by a reader knowing what to expect.

From a writing style, I think it would be really helpful to detail more examples. Presumably, the intention here is to appeal to a broad audience from really different research backgrounds. Assuming this is the case, I feel providing the specifics of more examples could be beneficial in helping readers grasp concepts they are less familiar with and to be engaged in research from other fields – some of the sections I enjoyed reading most took more of this approach.

I also think there is a need for a bit more self-reflection on behalf of the authors. I think the general idea clearly has something to it, but there are a few key considerations that are consistently underplayed or avoided (in part because they are tricky!). There is a need for clearer definitions of some of the terms used when describing political systems (e.g. an early example is in describing election results as sub-optimal without highlighting that this is not necessarily universally true, certainly by potential) or the lack of clarity on what "effective" governance is (is it enacting lots of policies or making the "right" decisions) and its meaning shifts through the article in different contexts. Similarly, very little attention is paid to the fact that not all animal groups reach consensus, and in some species groups often divide and rejoin (either in an ordered fashion or much more randomly) – consensus is common only in a select few animal societies. There are also very different pressures acting on social decision-making for non-human animal groups – e.g. the costs of leaving a group if "unhappy" may well be predation/death – the situation is altogether different in human democracies. Somewhere in the article the authors talk of decision ecologies and I think it would be good to do a broader compare/contrast of the similarities/differences in this regard. Finally, AI is often painted as an ideal solution to some of the problems discussed without considering some of the ethical considerations or indeed human factors in designing/implementing the algorithms used – think it is worth considering this.

It also feels that some of the benefits of one form of democracy/political system/collective behaviour may also be costs in a different context or at different scale. I think it would be interesting to consider how this is influenced by the wider context (e.g. scale/group size) or any differences between species or social systems. Providing a clearer synthesis of different forms of collective decisions in animal societies and what democratic systems/voting systems they are related to would be really great – perhaps there is a way to do this with a figure?

This is my first time reviewing for PCI, and it is tricky to know how the system works for a review/opinion piece like this. I guess my overall feeling is that there is some interesting information and insight in this article but overall, it is a little overwhelming as I'm not sure what I've learned after reading it or how it has moved ideas forward. To that end, it could be made much stronger through a clearer structure, more tangible links/lessons to learn and greater synthesis (in my opinion at least).

Line by line comments below:

L23 – how fair is this statement, versus individuals behaving selfishly?

L30-32: I think real care needs to be taken with the wording here. While I completely agree with you in terms of the outcomes, it is not immediately clear as to what makes the results described non-representative or sub-optimal without very careful definition. For example, the result in the USA (which I have some more knowledge) is representative with respect to how the voting system is set up (first past the post type system in each state) with it not being clear if this is the best or fairest system (especially when it differs from the popular vote as it did in 2016). Similarly, while a large number of people and entities would see the election of Donald Trump as sub-optimal this is far from universal (indeed, plenty of people voted for him again in 2020 so must have been happy with what he achieved for some reason...).

L33-35: Is there not considerable evidence (again I am aware mainly from the US and UK) of polarisation also increasing substantially between political parties with much less bipartisanship? Again, something to be cautious with in terms of writing/explanation.

L51-53: Completely agree with the sentiment of this statement but feel the parallels to human democracies are tricky and require clear caveats. For example, the descriptions of the problems in human democracies focus around voter dissatisfaction and turnout – it is very challenging to measure the satisfaction of individual animals with group movements (presumably those with individual optima further from the group optimum are more stressed, or to anthropomorphise, not best pleased!) and the costs of not maintaining a consensus are likely higher if there is a high risk of predation/death. I feel (and this may come later) that it is also very important to highlight this applies to particular animal groups and many other break up and reform in an ordered or even close to random way depending on the social system involved (i.e. various types of fission-fusion dynamics).

L95-96: The second part of this sentence is crucial and more needs to be made of it.

L98-100: This sentence needs to be expanded further so the logic is clearer.

L105: What is meant here by ineffective leadership? It strikes me that the majority system can enhance the ability of governments to effect policies (especially when they have an overall majority) but this governance may not be as likely to be universally beneficial/well-received/effective in improving society (c.f. for example, decision in a minority of coalition government).

L107-109: I think that this argument is that with low turnout and a small majority you cannot be sure that a majority in the sample is representative of the population as a whole, but this takes some interpolation – it would be good to see this explained a little more clearly.

L109-110: Need explaining in greater depth, feels like a bit of a throwaway sentence at the moment.

L127-129: Important to be clear with what you mean by sub-optimal here. It would be good to have a worked through or illustrated example of how these two systems work side-by-side to help the reader distinguish between them.

L136: What do you mean by “decision ecology”? New jargon and not explained.

L139-141: Again it would be good to explain/define sub- and supermajority quorums – could they be included in the glossary?

L141-143: How does this differ from the types of voting systems that are widespread (and often heavily criticised) such as the first past the post system of voting for MPs in the UK. This seems to be an example of creating independent smaller groups of voters (each constituency) and then using a majority rule within each group. Or indeed larger systems such as the Welsh Senedd or European elections for MEPs with different

rules? But then this makes me think I am misunderstanding the point being made here?

L143-144: This seems important – would good to read more about the general patterns, current statement is very vague.

L150-152: Feels this could/should have citations to support it. Not my field but <https://doi.org/10.1016/j.cub.2015.01.037> seems relevant.

L158-160: I think this concept needs expanding on a little – it also seems at some point to require a subjective decision to be made by someone.

L163-166: I get a bit lost here as to the role/use of AI. Is this voting systems for AI or using AI for human democracies as the implications seem rather different.

L201-203: But who sets these algorithms and decides what is representative (presumably there is sampled information used to come to make these decisions).

L200-206: I am hoping these points will be expanded upon below? Would be good to have something at the end of the paragraph indicating this will happen perhaps?

L215-218: How does group size play into this? I wonder whether scale is important here – it seems easy in practice for an animal group with a few tens or hundreds of individuals and I imagine small groups of humans use similar methods when making decisions often (e.g. a fairly direct analogy would in deciding whether to stay in a bar or move to a new one on a night out), but how feasible (and efficient?) is this approach at the level of a country? Does it risk potentially generating some of the problems discussed previously (lower turnouts with regular votes) or controversial/disputed results based on low levels of knowledge? The latter is touched on here but only in passing.

L226: I wonder whether there is an interesting example provided by the pandemic here?

L255-257: Not immediately clear to me how this is directly analogous. Surely, it is more equivalent to a situation where is someone is more enthusiastic they vote more times (probably most similar to phone voting in TV talent contests perhaps!). The link to Borda counts needs some more steps of explanation.

L220-276: I thought this section was really interesting and well-written overall.

L289: Perhaps better (and more universal) to refer to this as misinformation?

L297: Similar to various previous comments it would be good to ensure clarity with what “vote well” means – as identified this is where heterogeneity is important between voters. In addition, people may end up voting on particular issues rather than the entirety of what a leader stands for which can compound things further in terms of voting “well”.

L314: This is easy in the case of clearly misleading or incorrect stories, but some of the problem arise from other information that can have different meanings depending on how it is presented – perhaps hard or unfair to remove algorithmically and (again) rather subjective.

L323: Another important component is how easy it is to share these articles (e.g. Twitter now prompts a user to consider reading a link before sharing it, which is an interesting development in this regard).

L324-332: Interesting paragraph but a lot of new ideas here that are covered really very briefly. Would be good to introduce concepts like social networks (first real focus on this), the majority illusion/friendship paradox and small world networks with greater explanation to help readers along.

L367-368: Typo in this sentence somewhere.

L383-385: This distinction isn't especially fair, humans in small groups make decisions in similar ways everyday (whether it be friends on a walk, businesses, sports teams etc.). So perhaps it doesn't scale to our political systems but perhaps the general patterns aren't so distinct.

Box 1:

General points: I found the key ideas in the box, and the distinction between them to be rather hard to follow – I found myself using Wikipedia alongside the text to help understand the concepts better. It's also not clear from the text that Arrow's “proposal” is also a paradox, which is what is suggested by the figure?

L83: You switch from talking about cities to studies here

C. Sen Theory, is this the same as the other two? It would appear to be people voting with more information rather than a system for deciding how the outcome is decided?

Box 2:

This is nicely explained in general, but it is not representative of the full diversity of scenarios. As highlighted in a previous comment the full consensus being achieved occurs in not all species and not all contexts. Often only partial consensus can be achieved and groups split.

L172-174: A qualification is needed here as not all animal groups are democratic.

L177: Perhaps best to say it has been documented in, as it seems highly likely to occur in other taxa too

Box 3:

L340-342: This is very vague – not clear what would be achieved or how from what is written here

Reviewed by [Camelia Florela Voinea](#), 26 May 2021

From my point of view, the preprint is really interesting, however not necessarily as an interdisciplinary approach to voting systems, but to human collective decision-making which could find some insight in animal world and some support in AI research.

I have two main observations to provide with respect to the approach suggested in this preprint:

First, the text appears as a literature review with respect to two main issues, (1) collective decision-making in the animal world with support from studies of intelligent non-human agent behavior (bees, ants, animals), and (2) artificial intelligence and machine learning studies which could get insight in such behaviors in order to provide solutions to replicate these behaviors, (voting behavior, especially) in AI-based research approaches to human voting systems. As a literature review, the text mentions (sometimes, without explicitly explaining what exactly the refereed systems are actually performing in terms of voting tasks) various applicative and/or fundamental research in voting systems viewed as collective decision-making systems. With regard to this dimension, one should notice that collective decision-making in the living non-human animal world cannot escape the notion of 'dominance' regardless the contribution of each such individual agent to the collective decision (see: J.L. Gould on animal behavior, animal navigation, language; G.J. Hofstede on synthetic cultures inspired by animal world). It is therefore with precaution that we could approach collective decision-making in the living non-human animal world in order to get inspiration for improving human voting systems. In the animal world, collective decision-making cannot be assimilated or identified with voting behavior in humans as the voting is a reflexive process in humans, and it is usually employed in the dynamics, change or even in the self-organization of human organizations or social systems. There is no 'democracy' dimension in the animal world in spite of apparent individual contributions in collective decision making to group final decision connected to tasks like the searching for food resources (for example, in ants and bees social systems) or defending from enemies (for example, in wolves groups). As a literature review however, the preprint is interesting because it makes references to several research approaches which could inspire the research on human collective decision-making in participative societies, which is essentially different from what actually 'voting system' means. Perhaps, it might be useful to remind the huge literature and research work developed at M.I.T. (to take but this one example) on how studying the non-human behavior could enhance developing artefacts and artificial intelligent systems which could assist or replace humans (I like the 'avatar' example in this preprint!) in collective decision making. I still remember Rodney Brooks and his pioneering research work and I find useful to combine in the interdisciplinary research the studies on animal world with studies on human social and political systems. However, this kind of research (which has meanwhile produced intelligent robots able to perform amazing tasks as humans do) is different from the political human-world of decision making, so I would recommend care in making parallels between human and non-human voting systems or what appears to be a voting system in the animal world, but in fact it is not such one.

Second, the preprint aims to improve on voting systems by employing characteristics of collective decision-making in the animal world, like for example knowledge. I would make a brief comparative analysis and evaluation (if I may) with a research project on the same issues which has been developed some years ago, but which has not got any follow up (at least, to my knowledge) due to issue complexity: Social Collective Intelligence (Miorandi et al., 2016) is an approach which combines AI with several aspects of human behavior, human action, human decision-making, and human political organization rules. In this project, many aspects of human society and polity are approached from an AI perspective combined with ALife, AA and ML. These two approaches have something in common: they aim to improve human systems by AI systems. While the approach in Miorandi et al., (2016) reports research concepts, architectures, systems and performances, the approach in this preprint reports a literature review in studies on animal behaviors which could be assimilated to human behaviors and translated into artificial intelligent systems able to assist humans. As far as this preprint keeps a literature review approach, the text should further include research which could explain how AI and ML could be employed in extracting and/or achieving aspects of behavior which could further benefit human societies and polities. As far as this preprint aims at improving human voting systems, than 'voting system' and 'collective decision-making' should be defined and compared, and the approach should explain how studies on (non-human) animal behavior could touch on democratic dimensions of human voting and not only on human collective decision-making. It should also take into consideration various models of voting systems (rational choice theory, welfare, psychology, geometry & complexity, etc.).

Some informal references:

J.L. Gould: *The Honey Bee* (1988), *The Mystery of Animal Navigation* (2012)

Miorandi et al., (2016) *Social Collective Intelligence. Combining the Powers of Humans and Machines to Build a Smarter Society*, by Daniele Miorandi, Vincenzo Maltese, Michael Rovatsos, Anton Nijholt, James Stewart, Springer.

Hofstede, G.J., Pedersen, P. (1999) *Synthetic Cultures: Intercultural Learning Through Simulation Games*, December 1999, *Simulation & Gaming* 30(4). DOI: 10.1177/104687819903000402

Types of Voting systems/Models of voting: welfare (Arrow, K., 1950), economic model of voting in a democracy (Downs, 1958), voting models based on politics of ideology (Hinich & Munger, 2008; Enelow & Hinich, 1990), psychology of participation in human voter (Cox, 1997), political manipulation (Riker, 1986), calculus of voting (Riker & Ordeshook, 1968), complexity & geometry of voting (Saari, 2008).