

Societal-Scale Decision-Making Using Social Networks

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Abstract

In societal-scale decision-making systems, a collective is faced with the problem of deriving a decision that is in accord with the collective's intention. Modern political institutions utilize representational structures for decision-making such that any individual in the society can, in potential, participate in the decision-making behavior of the collective—even if only indirectly through a proxy representative. An agent-based simulation demonstrates that in traditional representation structures, as the size of the total population increases linearly relative to the number of decision-making representatives, there is an exponential increase in the likelihood that decision outcomes will not accurately reflect the preferences of the collective. In the direction of a remedy, this paper describes a novel social network-based method for societal-scale decision-making which greatly improves the accuracy of representative decision outcomes. This work shows promise for the future development of policy-making systems that are supported by the computer and network infrastructure of our society.

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In societal-scale decision-making systems, a collective is faced with the problem of deriving a decision that is in accord with the collective's intention. Modern political institutions utilize representational structures for decision-making such that any individual in the society can, in potential, participate in the decision-making behavior of the collective—even if only indirectly through a proxy representative. An agent-based simulation demonstrates that in traditional representation structures, as the size of the total population increases linearly relative to the number of decision-making representatives, there is an exponential increase in the likelihood that decision outcomes will not accurately reflect the preferences of the collective. In the direction of a remedy, this paper describes a novel social network-based method for societal-scale decision-making which greatly improves the accuracy of representative decision outcomes. This work shows promise for the future development of policy-making systems that are supported by the computer and network infrastructure of our society.

Social Compression and the Overload Problem

Collective decision-making is central to collective action. The *overload problem* occurs when a collective does not have the information-processing infrastructure to support the active participation of all its constituent members in all decision-making processes [Fischer 1999; Rodriguez 2004]. To overcome this issue, societies have come to approximate full participation by using a set of decision-making representatives. This approximation is analogous to a computer scientist's concept of "lossy" data compression where some loss of information is tolerated in order to reduce the resources required for storage or communication. Accordingly, we can call the use of representative decision-makers *social compression* and measure the amount of information loss as the ratio between those being represented to those representing. A lossless 1-to-1 representational structure is the case when all individuals are representatives of themselves, a direct democracy. At the other extreme, when the ratio of representation reaches an all-to-1 model, one individual is the autocratic representative of all members in the group. This lowest-resolution representation structure is a gross lossy model of the group since the ability to represent the perspective of every individual becomes increasingly difficult as the size and diversity of the group increases [Rodriguez 2004].

Most modern democratic institutions lie in between these two extremes, a regime where the number of active decision-makers is large enough to represent large-scale trends in public opinion but small enough to keep communications overhead manageable. As a rough illustration, the current resident population of the United States is estimated by the U.S. Census Bureau to be approximately 293 million (as of 2004) while the size of U.S. Congress is fixed by law at 535 members. This gives a representation ratio of approximately one policy-maker per 547,000 citizens. Presumably, there is a congressional membership limit because the communications overhead required to conduct traditional parliamentary process has a practical ceiling; yet there is also the simple fact that the architecture of the congressional meeting chamber permits only a limited number of seats. As human population increases, and the ratio of representation grows more severe, such artificial constraints on the policy-making infrastructure of a society become increasingly disabling.

This paper considers and compares traditional representational structures for collective decision-making with a newly proposed model based on the dynamic delegation of power across a social network. First we describe the proposed model and give its mathematical formalization. Next we present the results of an agent-based simulation of both the traditional and proposed models. This is followed by a discussion of implications for the future development of societal-scale decision-making systems that are supported by the computer and network infrastructure of our society.

Model Description and Simulation Results

In this section we describe a simple computer model of collective decision-making in order to compare two alternative forms of representation: 1) a traditional form in which representatives' opinions are weighted equally when making a decision; 2) a novel form in which the underlying social network of the collective is used to adjust the relative weight of representatives' opinions. As we will show, this latter method is more likely to accurately reflect the opinions of the whole collective.

The simulation represents an individual as a node within a network. Each individual node is assigned an "opinion" value from a uniform distribution between 0.0 and 1.0. Figuratively, one could imagine a node with a 0.0 opinion as an extreme conservative and an individual with a 1.0 opinion as an extreme liberal. Values in between

these bounds represent the diverse opinions of the general population. Given a set of participating decision-makers (representatives), a decision outcome is defined as the average of their opinion values (see equation 1). In the equations to follow, the set N denotes the entire population while the subset A represents the actively participating members ($A \subseteq N$). Equation 2 gives the expected decision outcome when the whole collective participates ($A = N$); this is the standard by which we measure how accurately the decision made by a subset (1) reflects the opinions of the whole.

$$GroupDecision = \frac{1}{|A|} \sum_{i=0}^{|A|} (opinion_i) \quad (1)$$

$$ExpectedDecision = \frac{1}{|N|} \sum_{i=0}^{|N|} (opinion_i) \quad (2)$$

Intuitively, the closer the number of actively participating individuals ($|A|$) is to the size of the total population ($|N|$), the more accurately the group is able to model the perspective of all its constituent members. The decision error of the group is determined by the absolute value of the difference between the calculated group decision (1) and the expected decision (2). Equation 1 is a complete description of the first form of representative decision-making we are considering where the opinions of participants are treated equally to produce an outcome. The second form (3) is identical except that participants' opinions are unequally weighted in order to more accurately reflect the opinions of non-participants. The $weight_i$ parameter in (3) is roughly the number of non-participants being represented by participant i (including i itself).

$$WeightedGroupDecision = \frac{1}{|N|} \sum_{i=0}^{|A|} (weight_i * opinion_i) \quad (3)$$

The method we choose to assign these weights is to presuppose the existence of a social network which represents trust relationships among members of the collective. This was our rationale for defining the collective as a network of individuals, each with a unique opinion. The following equation defines the amount of trust $node_i$ has in $node_j$:

$$Trust(n_i, n_j) = 1 - |opinion_i - opinion_j| \quad (4)$$

According to (4) similarity of opinions implies trust. Trust values are assigned as edge-weights on the directed edges of the social network. The only thing that remains to be defined is the method for calculating the weight values in (3) based on the social network topology and the strength of its pair-wise connections. To simplify calculations, we first normalize trust values on the outgoing edges of each node such that they sum to one. Now they denote percentages of one unit of trust given to the adjacent nodes. Figure 1 depicts a simple example showing trust connections among a four node collective with two active participants (shown by stars). The weight of each active node's opinion when calculating decision outcomes in (3) follows directly from the trust given them by non-active nodes.

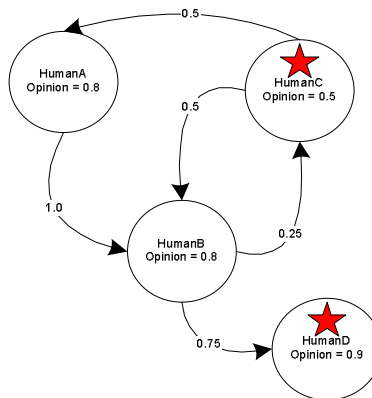


Fig. 1: Social network based on similarity of opinion

The great utility of this social network method is that we take advantage of trust transitivity. Decision power travels along paths of trust, automatically delegating to the active participants in a natural way. In the above example, human A trusts B completely and B divides trust unequally between C and D. We can imagine that each node is initially given one unit of trust which will be divided among its peers according to edge-weights. The process iterates with each node redistributing trust received on the previous iteration—except for active nodes which collect trust and do not redistribute. This continues until all trust has been aggregated to the set of active nodes. Note how this implies a kind of conservation of energy. Formal algorithms for this aggregation process are presented by [Steinbock & Rodriguez 2004]. Another important topic which is not covered in this paper is that, since we trust different people for different things, individuals would need to use a different set of peers for different subject domains of decision-making (see the discussion of organizational domain modeling in [Rodriguez 2004]).

For the example illustrated in fig. 1, we apply (2) to get an expected decision of 0.75 $[(0.9+0.8+0.8+0.5)/4]$. C's weight is 1.5 $[1.0 + .25 + .25]$, while D's weight is 2.5 $[1.0 + .75 + .75]$. According to the first decision method given by (1), the outcome would be 0.7 $[(.9 + .5)/2]$; compared against the expected decision this gives an error of 0.05. If we instead use the social network method (3), the outcome would be 0.75 $[(0.9 * 2.5) + (0.5 * 1.5)]/4$ giving us zero error for this example.

Now that a preliminary understanding of the social network method has been presented, we summarize the results of our simulation runs on networks of one hundred with constant connectivity (# of outgoing edges). Our intent was to measure the accuracy of decision outcomes relative to expected outcomes and compare the traditional method to our social network method. The results in figure 2 clearly show the advantage of our method at nearly all participation levels. While we also studied the effect of network connectivity, this parameter merely scaled the measured advantage by a constant factor. For clarity we only show data for network connectivity of three ($K \approx 3$), which exhibited the highest performance compared to the traditional method.

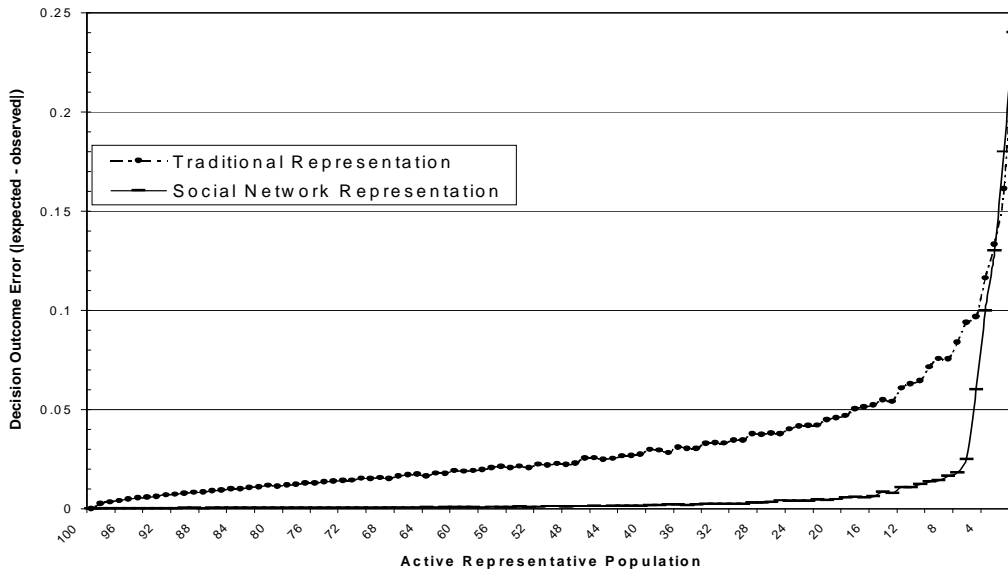


Figure 2: Accuracy of traditional representation vs. social network-based method

As expected, supplementing the traditional method with a social trust network for weighting the opinions of representatives resulted in a large decrease in decision error (as measured against the expected outcome). This result was especially dramatic when the active population was small relative to total population. The intuitive reason we see this result is that the use of a social network dampens the effect of a particular choice of representatives. Whereas the traditional method makes choosing representatives critical to the decision outcome—especially when the set is small—the social network smoothes out fluctuations so that a relatively stable model of the collective opinion is maintained.

Discussion and Concluding Remarks

Due to the overload problem, collective decisions are often made by a subset of the population; with respect to a given decision, this amounts to partitioning the collective into two sets: participants and non-participants. Participants are at minimum representatives of their own opinions but in practice represent the entire collective—insomuch that decisions determine collective actions. We have considered a traditional method of representational decision-making where decision outcomes derive solely from the opinions of the participating individuals. According to our simulation, this method results in an exponential increase in decision error as the set of representatives decreases in size (figure 2). However, by bringing to bear the knowledge implicit in a social network of trust relationships, the simulation indicates that this increase in error can be significantly dampened for nearly any number of representatives and any particular choice of representatives. This research has important implications for collectives whose availability of human resources fluctuates rapidly while the structure of the underlying social network is relatively stable. It offers a way to maintain a relatively stable approximation of collective opinion using nearly *any* subset of the population as representatives. This is analogous to a hologram, where any broken-off part of the whole image is in fact a lower-resolution version of the whole.

The idea of dynamic representation has an important role to play in the future development of societal-scale decision-making systems as public policy-making becomes more embedded within the medium of the world's modern network and computer infrastructure [Heylighen 2002; Turoff 2002]. The increasing complexity and interconnectedness of global society makes decentralization both necessary and attainable; formally, this complexity transition corresponds to a shift from hierarchical control structures to participatory networks [Bar-Yam 1997]. It is our position that dynamic representation is a critical part of this shift as it plays out in the context of public policy-making. In order to manage the complexity of global society, it will be necessary to replace the traditionally static, hierarchical forms of representation with new network-based models which adapt to the rapidly changing dynamics and contexts of decentralized society. It is our hope that future designers of large-scale human decision-making systems will find our social networks-based method of use in meeting this emerging need.

References

- [Bar-Yam 1997] Bar-Yam, Y., *Dynamics of Complex Systems*, Addison-Wesley, pp. 783-825, 1997.
- [Fischer 1999] Fischer, G., "A Group Has No Head: Conceptual Frameworks and Systems for Supporting Social Interaction", *Information Processing Society of Japan, IPSJ*, 1999.
- [Fjemestad & Hiltz 1997] Fjemestad, J., Hiltz, S., "Experimental Studies of Group Decision Support Systems: An Assessment of Variables Studied and Methodology", *Proceedings of the 30th Hawaii International Conference on System Sciences: Information Systems Track-Collaboration Systems and Technology*, 1997.
- [Heylighen 2000] Heylighen, F., "The Global Superorganism: an evolutionary-cybernetic model of the emerging network society", *Journal of Social and Evolutionary Systems*, 2000.
- [Kauffman 1993] Kauffman, S., *The Origins of Order: Self-Organization and Selection in Evolution*, Oxford University Press, 1993.
- [Rodriguez 2004] Rodriguez, M., "Advances towards a Societal-Scale Decision-Making System", *UCSC-Masters Thesis*, 2004.
- [Steinbock & Rodriguez 2004] Steinbock, D., Rodriguez, M., "Self-Modeling Dynamical Systems: A Social Networks Application", *International Conference on Complex Systems*, 2004.
- [Turoff 2002] Turoff, M., Hiltz, S., Cho, H., Li, Z., Wang, Y., "Social Decision Support Systems (SDSS)", *Proceedings of the 35th Hawaii International Conference on Systems Science*, 2002.