

# Smartocracy: Social Networks for Collective Decision Making

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## ABSTRACT

Smartocracy is a social software system for collective decision making. The system is composed of a social network that links individuals to those they trust to make good decisions and a decision network that links individuals to their voted-on solutions. Such networks allow for a variety of algorithms that convert the link choices made by individual participants into specific decision outcomes. Simply interpreting the linkages differently (e.g. ignoring trust links, or using them to weight a individual's vote) provides for a variety of outcomes fit for different decision making scenarios. This paper will discuss the Smartocracy network data structures, the suite of collective decision making algorithms currently supported, and the results of two collective decisions regarding the design of the system.

## Categories and Subject Descriptors

H.4.2 [Information Systems Applications]: Types of Systems—*Decision support*; K.4.3 [Computers and Society]: Organizational Impacts—*Computer-supported collaborative work*

## General Terms

Social Software

## Keywords

Social Networks, Societal-Scale Decision Support System, Particle Swarms

## 1. INTRODUCTION

The recent explosion of so-called ‘social software’ on the Internet has been characterized by democratic approaches to content generation. The Wiki is an exemplar of this approach, where all users have equal power to add or modify

the content of any hypertext [3]. Wikis are social software that support democratic collaborative authorship. Systems exist to support generative collaboration in many fields including, but not limited to, journalism<sup>1</sup>, scholarly citation<sup>2</sup>, photography<sup>3</sup>, and hypertext bookmarking<sup>4</sup>.

While these systems vary in the forms of collaboration they support, they have in common an egalitarian social structure and they all aggregate user contributions into shared representations of collective belief. For instance, in addition to contributing news stories, users of the Digg web service vote for stories they think highly of and can view the most popular stories for different subjects. Del.icio.us users save and categorize bookmarks for websites they like into a common pool and can easily view the most popular sites for any category. Similar patterns of contribution and aggregation occur with varying prominence throughout the social software sphere. Despite the proliferation of such systems and their parochial methods of aggregation, there has yet to emerge a generalized software model for the intelligent aggregation of individual contributions beyond mere vote-counting. If such a model did exist, it could systematically improve the state of the art in social software design and promote the innovation of systems geared more directly toward the aggregation of individual knowledge into collective knowledge, i.e. software supported collaborative problem solving and decision making [1, 9].

Smartocracy<sup>5</sup> is a web-based social software system for collective problem solving/decision making. Smartocracy uses a problem-solution model where individuals can pose problems (i.e. issues, questions) to the Smartocracy community and then propose potential solutions (i.e. options, answers). The proposed solutions are voted on and the aggregate preferences of all individual users yield the collective decision. To further facilitate vote-based decision making, a trust-based social network is used to represent the relations among users and, in some cases, to support the auto-

<sup>1</sup>Digg available at: <http://digg.com>

<sup>2</sup>CiteULike available at: <http://citeulike.org>

<sup>3</sup>Flickr available at: <http://flickr.com>

<sup>4</sup>Del.icio.us available at: <http://del.icio.us>

<sup>5</sup>Smartocracy available at: <http://www.smartocracy.net>

mated delegation of decision making power along paths of trust. This paper discusses trust-based decision making theory, the Smartocracy system implementation, and concludes with the results of the Smartocracy community’s system development decisions as of March 2006.

## 2. COLLECTIVE DECISION MAKING

Collective decision making, in the context of Smartocracy, involves individuals generating problems, providing potential solutions, voting for solutions, and the software aggregating individual votes and ultimately deriving a final collective decision. Figure 1 provides an outline of Smartocracy’s collective decision making process.

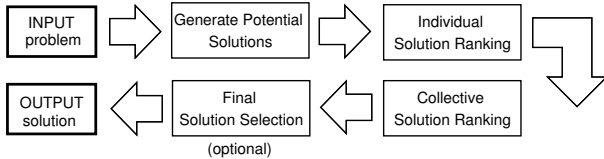


Figure 1: Smartocracy’s collective decision making stages

Given a particular problem, any individual in Smartocracy can propose a potential solution. Individuals can also vote for a proposed solution. By voting for particular solutions, individuals are explicitly providing their individual ranking of the problem’s solution set. The suite of Smartocracy collective solution ranking algorithms, aggregates all the individual votes into a collective solution ranking. Collective ranking algorithms currently supported by Smartocracy are direct democracy [4], dynamically distributed democracy [6], and proxy vote [7]. The result of the collective solution ranking algorithm serves as input to a solution selection function. For nominal, or categorical, based solution sets, the highest ranked solution is considered the collective decision. For numeric, or gradient, based solution sets, a weighted average selection function is calculated based on their respective rank. The result returned by the selection function is the collectively derived solution to the problem. It is important to note that the solution selection function is an optional step that is used only if a single definitive solution is required. In some cases, the solution to the problem may be the collective ranking itself.

## 3. THE NETWORKS

Social networks are used to represent the relationships between individuals of a population. Most commercial social network systems (e.g. MySpace<sup>6</sup> and LinkedIn<sup>7</sup>) denote static relational ties between users, such as ‘is a friend’ or ‘is a colleague’. For collective decision making, friendship is not necessarily the desired semantic relationship. In collective decision making, stating that an individual is a friend does not identify them as a good decision maker. Therefore, a collective decision making social network must make explicit the notion of decision making trust. For instance, if individual  $A$  provides individual  $B$  with a trust edge, then

<sup>6</sup>MySpace available at: <http://www.myspace.com>

<sup>7</sup>LinkedIn available at: <http://www.linkedin.com>

$A$  is stating that he or she trusts  $B$  to make a good decision.

There exist other artifacts in the system besides human individuals. These artifacts include problems (i.e. current issues being addressed by the collective) and solutions (i.e. potential options for a particular problem). Therefore, the graph data structure underlying the Smartocracy system is a graph connecting individuals according to their relative trust of one another and connects individuals to particular solutions via edges that denote a vote. The network data structure describing this system can be formally denoted as  $G = \{N, W\}$  where  $N$  is a collection of human ( $H$ ), problem ( $P$ ), and solution ( $S$ ) nodes and  $W$  is the set of weighted semantic relationships between these entities. Note that  $N = H \cup P \cup S$ ,  $H \cap P \cap S = \emptyset$ , and  $w_{n_i, n_j}^\lambda$  states that there exists a directed, weighted relationship of semantic  $\lambda$  between  $n_i$  and  $n_j$ . The only semantic relationships currently supported by Smartocracy are  $\lambda = \{\text{trusts}, \text{votedFor}\}$ .

The connection between the trust-based social network and the vote-based decision network is represented in Figure 2 where the solid edges represent the weighted trust relations amongst individuals and the dashed edges represent the weighted votes that individuals provide for particular solutions to problems. The following two sections will further discuss each network’s constructs.

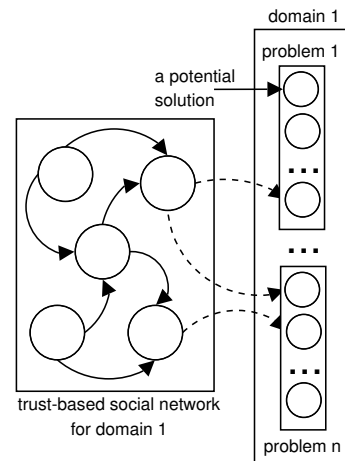


Figure 2: The connection between the social and decision networks

### 3.1 Trust-Based Social Network

In the Smartocracy trust-based social network, an edge going from individual  $h_i \in H$  to  $h_j \in H$  states that  $h_i$  believes that individual  $h_j$  is ‘good’ at decision making where  $i \neq j$  and  $H \subseteq N$ . In this model,  $h_j$  may not trust the decision making behavior of  $h_i$ . Therefore, the trust-based edges between individuals are directional. Furthermore, individual  $h_i$  may weight the relative trustworthiness of individual  $h_j$  and, in such cases, an edge can be represented by the conditional probability,

$$w_{h_i, h_j}^{\text{trusts}} = P(h_j \text{ is good} \mid h_i \text{'s knowledge of } h_j).$$

This relationship states that  $h_i$  trusts, according to some probability, that  $h_j$  will make a good decision given  $h_i$ 's previous understanding of  $h_j$ . What this edge model lacks is a representation of the domain for which trust is given. Because humans are multi-dimensional entities composed of various skills and beliefs, individual  $h_i$  may trust the decision making behavior of  $h_j$  in one domain but not another. Therefore, it may be more appropriate, given a decision making scenario, to state,

$$w_{h_i, h_j}^{\text{trusts}} = P(h_j \text{ is good in domain } d_l \mid h_i \text{'s knowledge of } h_j \text{ in domain } d_l).$$

There are multiple ways to represent domains in a social network context [7]. Currently, due to the focused use of Smartocracy, there exists only a single social network and therefore, no explicit representation of domains. As will be demonstrated in the results section, domain specific representation is a collectively desired feature for future implementation.

### 3.2 Vote-Based Decision Network

In Smartocracy, any individual that votes for a potential solution is creating a directed edge from themselves in  $H$  to a solution in  $S$ . The semantic of this relationship is  $\lambda = \text{votedFor}$  and can be represented by the conditional probability,

$$w_{h_i, p_j(s_m)}^{\text{votedFor}} = P(s_m \text{ is a good solution for problem } p_j \mid h_i \text{'s knowledge of } p_j).$$

The above vote edge states that human  $h_i$  believes that, according to some probability,  $s_m$  is a good solution for problem  $p_j$ .

The weighted ranking that an individual provides for the solution set to a particular problem is their subjective evaluation of the relative optimality of the solutions for the problem. These are called the individual solution rankings. To move from an individual solution ranking to a collective solution ranking, an aggregation algorithm is required. The next section will discuss the algorithmic framework used to calculate collective decisions within the trust-based social network and the vote-based decision network.

## 4. ALGORITHMS FOR COLLECTIVE SOLUTION RANKING

Given a trust-based social network and a vote-based decision network, Smartocracy supports a family of algorithms for aggregating individual votes into a collective solution ranking. The currently implemented algorithms are direct democracy, dynamically distributed democracy, and proxy vote. All of these algorithms are implemented under the parameterized particle swarm framework described in [5, 7].

In a particle swarm, a particle is considered an ‘atom’ of decision making influence. To calculate a collective solution ranking for a particular problem, particles begin their journey at human nodes and make their way to the solution nodes of that problem via the trust-based social network and vote-based decision network. Because particles are discrete, indivisible entities, the diffusion of particles through a network requires a sufficient initial distribution to expose the underlying network topology. The more particles initially supplied to the network, the more accurate the collective ranking. At the end of the particle propagation algorithm, when all particles have either been destroyed or have reached a solution, the distribution of particles over the solution set of the problem determines the collective’s solution ranking. This section will describe the specifics of each of the three collective solution ranking algorithms currently supported by Smartocracy.

### 4.1 Direct Democracy

Direct democracy embodies the idea of ‘one-person/one-vote’ [4]. In direct democracy, the trust-based social network is *not* used to calculating the collective decision. If the individual does not vote, then the individual does not participate. If an individual does not participate, then he or she does not influence the collective solution ranking. To implement this algorithm within the particle swarm framework, each individual is supplied with 100 particles. A particle can only traverse a votedFor edge,  $w_{h_i, p_j(s_m)}^{\text{votedFor}}$ . The probability of traversing one votedFor edge over another is dependent upon the edge weight assigned by the voter. Strongly weighted edges have a higher probability of being traversed by the particle. If the individual has not voted, then the particle destroys itself. After one step, all particles are either destroyed or are at a particular solution node to problem  $p_j$ . The distribution of particles over the solution nodes represents the direct democracy collective solution ranking.

Figure 3 provides an example of the possible paths of a direct democracy swarm. Humans  $h_1$ ,  $h_2$ , and  $h_3$  are each provided 100 particles. After the first step,  $s_1$  will have accumulated approximately 50 particles,  $s_2$  60 particles, and  $s_3$  90 particles. Note that the particles given to  $h_2$  are destroyed since  $h_2$  has not voted on a solution. The normalized distribution over the solution set is  $s_1 = 0.25$ ,  $s_2 = 0.30$ , and  $s_3 = 0.45$ . This normalized distribution is the direct democracy collective solution ranking. If the solution set is a nominal solution set, then  $s_3$  is the collectively derived solution according to a highest rank solution function.

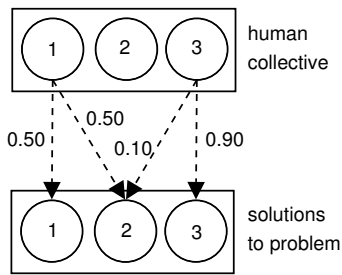


Figure 3: Direct democracy particle paths

## 4.2 Dynamically Distributed Democracy

Dynamically distributed democracy, or DDD, was developed to handle issues concerned with fluctuating levels of participation. In such cases, ad hoc representative structures are created to ensure that every individual can influence the collective solution ranking even if only through a proxy representative. This algorithm has been shown to be an accurate way to model the collective's perspective as voter participation wanes [6].

In DDD, a particle, if it is unable to take a vote edge to a particular solution, uses the trust-based social network to move to a proxy representative. If that representative has voted, then the particle moves to one of the representative's chosen solutions. If the representative has not voted, the particle traverses a trust edge to move to yet another representative. This iterative process continues until a solution to the problem is found or a maximum number of steps has been reached. For Smartocracy, the upper limit on particle propagation is set to 100 steps.

In Figure 4, human  $h_2$  has not voted on a particular solution. In DDD,  $h_2$ 's decision making influence is, or particles are, delegated to human  $h_1$  because  $h_2$  trusts  $h_1$ ,  $\exists w_{h_2, h_1}^{\text{trusts}}$ . Therefore,  $h_1$  has 200 particles to provide to his or her chosen solutions. After two steps, solution  $s_1$  will have 100 particles,  $s_2$  will have 110 particles, and  $s_3$  will have 90 particles. The normalized distribution over the solution set is  $s_1 = 0.33$ ,  $s_2 = 0.36$ , and  $s_3 = 0.30$ . If the selection function selects the highest ranked solution, then solution  $s_2$  would be the collectively derived solution.

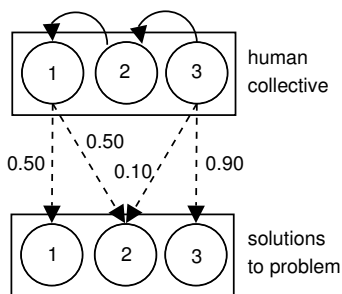


Figure 4: Dynamically distributed democracy particle paths

Notice that because  $h_3$  provided a vote, the particles initially provided to  $h_3$  do not traverse the social network. That

is,  $w_{h_3, h_2}^{\text{trusts}}$  is not used in the DDD computation. Furthermore, in the case that every individual votes for a particular solution, the DDD algorithm will provide a collective solution ranking that is equivalent to the direct democracy algorithm's ranking. DDD is useful in problem domains where it is desirable for every individual to have an equal say (i.e. influence) in the collective's decision, but it is not feasible for every individual to actively participate via voting. In such cases of reduced participation, ad hoc representative structures emerge to simulate full participation.

## 4.3 Proxy Vote

Proxy vote is an extension of DDD where the initial distribution of particles is biased by the trust-based in-degree of an individual. That is, the more a particular individual is trusted, the more particles that individual initially receives. This algorithm is used for expert-based problem domains where an equal say for every individual is not desired. For proxy vote, it is assumed that the in-degree of the individual is a representation of his or her level of expertise.

In Figure 5, human  $h_1$  is supplied with 200 particles,  $h_2$  200 particles, and  $h_3$  100 particles. The number of particles at  $h_1$  and  $h_2$  is double that of  $h_3$  because both  $h_1$  and  $h_2$  have one incoming trust-based edge and each incoming edge provides an extra 100 particles to an individual. As in the DDD example,  $h_2$  disseminates his or her received particles to  $h_1$  since  $h_2$  trusts only  $h_1$  and  $h_2$  has not voted on a solution to the problem. Therefore,  $h_1$  has 400 particles to distribute to his or her chosen solutions. After the second step, solution  $s_1$  will have 200 particles,  $s_2$  210 particles, and  $s_3$  will have 90 particles. The normalized distribution over the solution set is  $s_1 = 0.40$ ,  $s_2 = 0.42$ , and  $s_3 = 0.18$ . Given a highest rank selection function,  $s_2$  would be the collective decision.

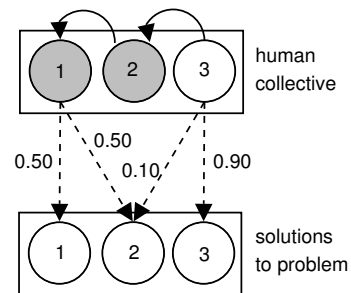


Figure 5: Proxy vote particle paths

## 5. SMARTOCRACY BETA RESULTS

Smartocracy was released for beta testing in February of 2006. New users join the system via an invitation from a currently existing user. Each individual, once invited, can create 10 trust-based edges to other individuals. An invitation of someone new automatically creates a directed edge from the inviter to the invitee. Furthermore, weighted trust is possible by providing multiple links to the same individual. This is represented as a single link with a weight of 10. Also, throughout the life of the system, individuals can reassign their outgoing trust-based edges. The interface to

view one's incoming and edit one's outgoing trust edges is shown in Figure 6.

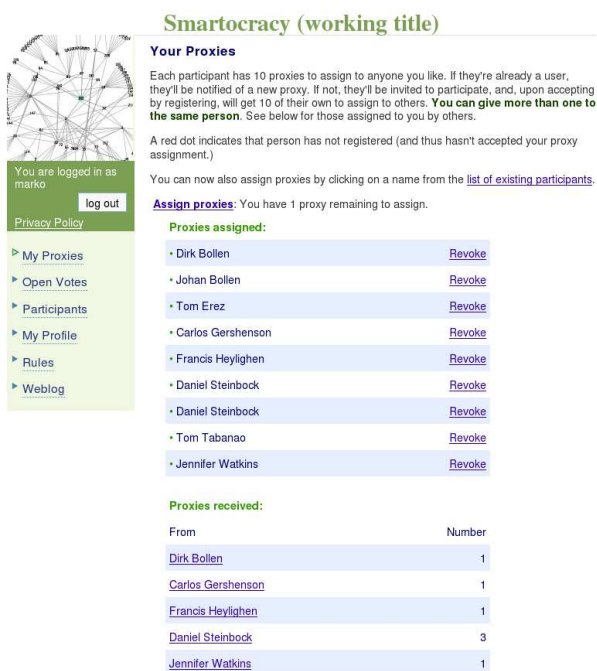


Figure 6: An individual's in and out trust-based edges

Figure 7 provides a visualization of the 276 participants in the Smartocracy trust-based social network as of March 7, 2006.

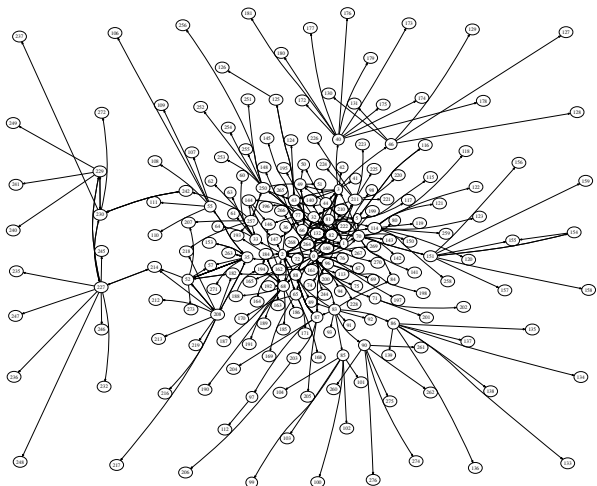


Figure 7: Visualization of the Smartocracy network as of March 7, 2006

The current in-degree edge distribution is presented on a log/log plot in Figure 8. Like most real world networks, the Smartocracy social network's edge distribution follows a power-law. For the function  $P(\text{in-degree}) = a \times \text{in-degree}^{-\gamma}$ ,  $\gamma \approx 2.4$ . This function computes the probability that any

given node will have a particular in-degree. As can be seen in Figure 8, there exist many individuals with few incoming trust edges and few individuals with many incoming edges. As depicted in Figure 8, more than 75% of all individuals in the network have 1 incoming edge while only 0.4% of the individuals have 8 incoming edges.

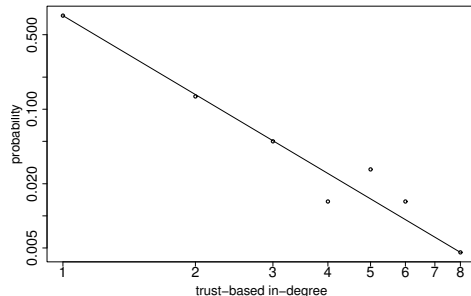


Figure 8: Smartocracy social network in-degree edge distribution

The remainder of this section will provide some preliminary results of two initial problems posed to the Smartocracy collective. The two problems, in the form of questions, are:

1. What should the name of the system be?
2. What features should we add to the system?

These problems are self-reflective in the sense that they concern the system itself. The goal of the beta test period is to develop a system that is palatable to the collective. For this reason, it is thought best to allow the users to provide development solutions and thus regulate the system's evolution via the collective.

### 5.1 System Name

The system name problem was posed by the developers in order to determine the most appropriate name for the service. Any individual could provide a potential name solution as well as vote on which names they preferred. Table 1 provides the 13 potential names that were provided by the group.

A visualization of the vote interface to the system is provided in Figure 9. Between the time the initial decision making data was analyzed and the screenshot was taken, a new system name, Dynamocracy, was proposed. Note that the new solution expresses the dynamic nature captured in the difference between Table 1 and Figure 9.

Figure 10 provides the ranking of the 13 potential solutions according to the direct democracy algorithm. Of the 276 participants in the system, 95 voted. Therefore, only 34% of the group contributed to the direct democracy collective

	potential solution
1	DecisionNet
2	DDD
3	Dis Dis Sys
4	Cell of the Elite
5	Smart Mob Rule
6	Smartocracy
7	Holocracy
8	netocracy
9	Wisism
10	Stupocracy
11	Cheerocracy
12	antpile
13	Decision Network

Table 1: System name solutions

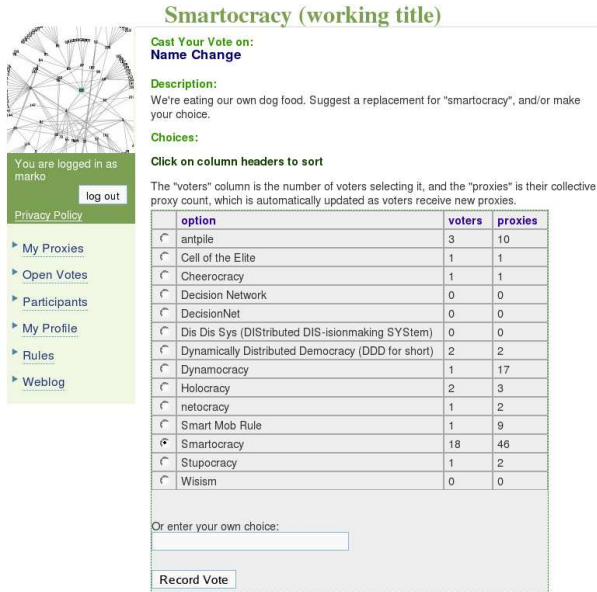


Figure 9: Creating and voting on solutions screenshot

solution ranking. With a highest rank selection function, the name Smartocracy, is the final collective decision.

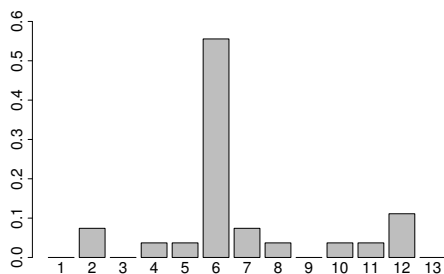


Figure 10: Direct democracy system name ranking

Figure 11 provides the ranking of the 13 potential solutions according to the dynamically distributed democracy algo-

rithm. In DDD, the 181 non-participants delegated their decision making influence (particles) to their trusted proxy representatives. Given a highest rank selection function, Smartocracy is again the collective decision.

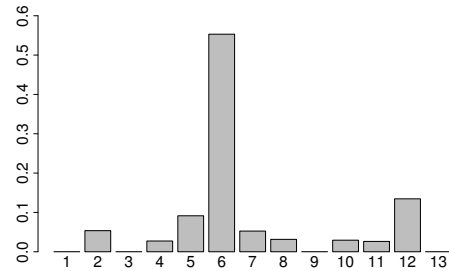


Figure 11: Dynamically distributed democracy system name ranking

Finally, Figure 12 provides the ranking of the 13 potential solutions according to the proxy vote algorithm. Smartocracy is once again the highest ranked solution.

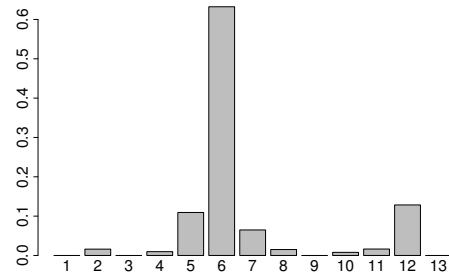


Figure 12: Proxy vote system name ranking

Table 2 provides the Spearman  $\rho$  correlations between the various algorithms' collective solution rank distributions where dd is direct democracy, ddd is dynamically distributed democracy, and pv is proxy vote. The strong correlations, with  $p$ -value  $< 2.2^{-16}$ , between the algorithms demonstrates the definitiveness of the collective's desired name choice. For this reason, Smartocracy is the current name of the system.

	dd	ddd	pv
dd	1.0	0.93	0.91
ddd	0.93	1.0	0.97
pv	0.91	0.97	1.0

Table 2: System name Spearman  $\rho$  rank correlations

## 5.2 Future Features

In line with today's widely-used strategies for social software development, Smartocracy was originally implemented in a bare-bones fashion with the desire that the group steer its future development. With this idea in mind, the problem "What features should we add to the system?" was posed to

the group. Table 3 provides the list of all proposed solutions generated by members of the group.

	<b>potential solution</b>
<b>1</b>	social network visualization
<b>2</b>	know if my proxies have taken action
<b>3</b>	domain specific proxies
<b>4</b>	Golightly Community
<b>5</b>	dialog with other participants
<b>6</b>	geo-based network viz

Table 3: Future features solutions

Of the 276 participants in the system, 98 voted for a future feature. Figure 13 depicts the direct democracy collective solution ranking over the 6 proposed solutions. According to direct democracy with a highest rank selection function, the collective desires to have a feature that allows individuals to know if their representatives, or proxies, have voted for a solution to a problem.

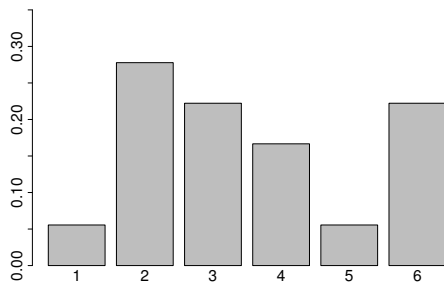


Figure 13: Direct democracy collective solution ranking for features

In Figure 14, the DDD collective solution ranking provides a different perspective of the collective’s desired future feature. Smartocracy was originally developed with a single trust-based social network. Therefore, decision making influence is delegated in the system irrespective of the domain of the problem. It became apparent to many users that they may trust someone in one domain, but not another. The DDD/highest rank decision shows that the collective is more interested in having domain specific proxies, or domain specific representatives. That is, decision making influence is delegated to representatives depending on the domain of the problem and the domain of the trust-based representation.

Finally, the proxy vote solution ranking is perfectly correlated with the DDD solution ranking and therefore, proxy vote shows that the collective is interested in having domain specific proxies. The proxy vote collective solution ranking is provided in Figure 15.

The Spearman  $\rho$  correlations between the various algorithm’s collective solution rankings are provided in Table 4 where  $p$ -value  $< 2.2^{-16}$ . Given the perfect correlation between DDD

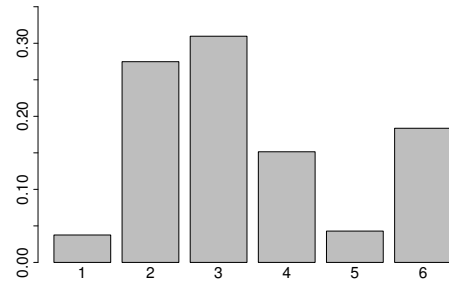


Figure 14: Dynamically distributed democracy collective solution ranking for features

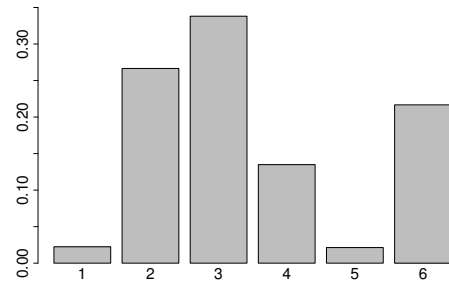


Figure 15: Proxy vote collective solution ranking for features

and proxy vote, the developers of Smartocracy are currently working towards implementing domains into the system as articulated in [7].

	<b>dd</b>	<b>ddd</b>	<b>pv</b>
<b>dd</b>	1.0	0.88	0.88
<b>ddd</b>	0.88	1.0	1.0
<b>pv</b>	0.88	1.0	1.0

Table 4: Future features algorithm Spearman  $\rho$  correlations

## 6. FUTURE DIRECTIONS

In spirit with the previously presented collective decision making processes, future development of the system will be guided by the requirements generated by the collective. As shown in the future features section, a major push in the development of this system will be the inclusion of domain specific representation. In [7], a model for adding domain specific representation to social networks is provided. Depending on the requirements of the Smartocracy group, one of the proposed models will be implemented.

Finally, in terms of future research in the area of collective decision making, we intend to explore various collective ranking algorithms for different classes of problems to understand which algorithms are best suited for particular decision making situations. Given a problem set with known optimal solutions, which algorithms best aggregate the perspectives of the individuals to yield the optimal solution? Such a study would expand the use of Smartocracy into the

domain of collective intelligence research and would bring Smartocracy to a level that is a generalization of domain specific collective intelligence systems like [2, 8].

## 7. CONCLUSION

Social systems, in order to make the ‘right’ decisions, require sensors capable of delivering relevant information. Polls have been used to collect information relevant for societal-scale decision making. The drawbacks of polls are well known: either they require public participation from a large sector of the population, or they might be biased and therefore, not representative of the collective opinion. By exploiting social network structures, systems such as the one presented here can overcome some of these drawbacks. With algorithms like DDD, only a small percentage of public participation is required to recover representative information. Thus, these algorithms are a form of social compression. For problem domains where general opinion is not desired, algorithms similar to proxy vote may better expose optimal solutions.

Smartocracy could be used to make social decisions within communities of any type, from frivolous to scientific, from political to educational: scientific peer review, project funding, school admissions, popularity contests, artistic awards, ethical decisions, judicial sentences. These are only some of the potential niches where the research presented in this paper could be exploited. The general idea is that in any domain, having better social sensors will necessarily lead to better social decisions.

## 8. ACKNOWLEDGMENTS

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## 9. ADDITIONAL AUTHORS

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