Abstract. We consider an electorate composed of both genuine and fake voters, aka sybils, and investigate the resilience of its decision making against two types of sybil attacks: Sybils enforcing decisions on the genuine voters, and sybils blocking decisions by the genuine voters. We follow Reality-Aware Social Choice and use the status quo as the anchor of sybil resilience, which we characterize by sybil safety – the inability of sybils to change the status quo against the will of the genuine voters, and sybil liveness – the ability of the genuine voters to change the status quo against the will of the sybils. We show that supermajorities are sybil-resilient for voting on a single alternative to the status quo, and describe several rules which are sybil-resilient for voting on multiple alternatives to the status quo. Specifically, we show that these rules are safe against arbitrarily-high sybil penetration, but can uphold liveness only if sybil penetration is under one third. We present a simple and efficient sybil-resilient Reality-aware Condorcet-consistent voting process and analyze its liveness as it depends on the degree of sybil penetration.

1 Introduction

In a majoritarian democracy, a single vote may decide the fate of elections or tilt a decision. Such a deciding vote could, in principle, belong to a fake voter, aka sybil. The risk of sybils infiltrating the electorate is even higher in online democratic communities, making sybil attacks literally an existential threat to e-democracies. To defend against this threat, we follow Reality-Aware Social Choice [11] in recognizing the status quo (Reality) as a distinguished, ever-present alternative and leverage it to face sybil attacks. Specifically, we use the status quo as the anchor of sybil resilience, which we characterize by sybil safety – the inability of sybils to change the status quo against the will of the genuine voters, and sybil liveness – the ability of the genuine voters to change the status quo against the will of the sybils (formal definitions are given below).

We first consider voting on a single proposal and show that a sybil-resilient supermajority, in which a simple majority plus half the sybil penetration rate is required to change the status quo, is safe. That is, for any $0 \leq \delta < \frac{1}{2}$, requiring a majority of $\frac{1}{2} + \delta$, referred to as a $\delta$-supermajority, makes the vote resilient to infiltration of up to $2\delta$ sybils.

Critically, for such a supermajority to withstand a sybil attack, all genuine voters must vote. While the mathematical framework presented here can be
extended to accommodate for such partial voter participation, our specific results here assume full voter participation; we explore mitigating partial participation in a subsequent companion paper [10].

Interestingly, a sybil-resilient supermajority is similar to Byzantine failures in its tipping point: Below one-third sybil penetration, it assures both safety and liveness, as a sufficiently-high majority of the genuine voters may effect a change of the status quo. Above one-third, it assures safety but not liveness, as sybils, while unable to force a change to the status quo, may block any change to it.

We then consider voting on multiple alternatives, one of which is the status quo (Reality), and define a sybil-resilient Reality-aware Condorcet winner to be an alternative preferred over all others by a sybil-resilient supermajority. We show this rule to be safe and, when sybil penetration is less than one third, to provide for liveness. We propose a sybil-resilient extension of the Amendment Agenda [3] that is sybil-resilient Condorcet consistent.

1.1 Related work

There is a vast literature on defending against sybil attacks (see, e.g., the recent surveys [1,13]). That literature is usually concerned with graphs on which the genuine and sybil entities reside, and the focus is usually not on voting. For example, Douceur [6] describes a very general model for studying sybil resilience and presents some initial negative results in this model. Many papers consider leveraging graph properties such as various centrality measures to identify suspicious nodes (see, e.g., the paper of Cao et al. [2]). As a further example, Molavi et al. [8] aim at shield online ranking sites from the negative effects of sybils.

Here we are interested in particular in sybil-resilient voting. This scenario is considered by Tran et al. [12], but with a different goal and solution: While we aim to protect democratic decisions from sybil attacks, they are considering ranking online content. Other relevant papers within computational social choice are the paper of Conitzer et al. [5] which concentrate on axiomatic characterizations of rules resilient to sybils in a certain formal model of elections. Our crucial difference is that we rely on Reality-aware social choice, and thus allow for conservatively default back to the status quo. Therefore, Conitzer et al. main negative result does not apply in our, Reality-aware model.

Other relevant papers are the paper of Wagman and Conitzer [15,16], which consider design of mechanisms to be resilient to false-name manipulation where the creation of sybils incurs some non-negligible cost. Waggoner et al. [14] study ways to evaluate the correctness of a certain election result when the number of sybils in the electorate is assumed to be known. Conitzer et al. [4] consider using connections in a social network to increase the effectiveness of sybil resilient methods.

2 Formal Model

Below we spell out our formal model, specifically formally defining sybil safety, liveness, and resilience.
We assume a set of identities $V = H \cup S$, $H \cap S = \emptyset$, that is a union of two disjoint sets, the set of genuine identities $H$ and the set of sybil identities $S$. These identities are the voters for which we wish to design sybil-resilient voting rules, each identity $v \in V$ is referred to as a voter. While we have a specific approach to defining and demarcating genuine and sybil identities [9], our results here are independent of our specific approach and only assume the existence of such a distinction.

We follow Reality-Aware Social Choice in considering elections with respect to a set of alternatives $A$ that includes the status quo $R$ (Reality) as a distinguished, ever-present alternative, $R \in A$. A vote $v$ is a particular ordering on $A$; i.e., we use the ordinal model of elections and let each voter express her opinion on $A$ by providing a ranking of $A$. For a given election, in this paper we assume that all voters cast a vote. (A companion paper [10] relaxes this assumption and addresses partial voter participation.)

We consider voting rules for such elections. Normally, a voting rule $R$ (i.e., a social choice function) is a function that takes a set of votes (linear orders) and returns a member of $A$ as a single winner. As ties are possible, a voting rule is expected to break them “behind the scenes”, typically arbitrarily. In this work, however, for technical reasons it will be useful to reify ties and tie breaking. Thus, in the following definition, a voting rule elects a set, interpreted as winning alternatives up to ties, which then may be broken explicitly.

**Definition 1 (Voting rule).** Given a set $A$ of alternatives, let $L(A)$ denote the set of all rankings over $A$. A voting rule $R : L(A)^n \to 2^A$ is a function that takes $n$ votes over $A$ and returns a set of elected alternatives. If a singleton is elected from $A$, then it is referred to as the winner of $R$ for the election. Otherwise, each of the alternatives returned from $R$ is referred to as a co-winner of the election.

We wish to have voting rules that are sybil safe, in the sense that they prevent sybils from changing the status quo against the will of the genuine voters. But how is the will of the genuine voters defined? Presumably, via an established voting rule, e.g., the majority rule when voting on a single proposal (against the status quo), or the Condorcet rule when voting on multiple alternatives. The following definition aims to capture this intent.

**Definition 2 (Sybil Safety).** Consider a set of alternatives $A$ with $R \in A$, a set of voters $V = H \cup S$, $H \cap S = \emptyset$, and let $R$ and $R'$ be two voting rules. We say that the voting rule $R$ is sybil safe with respect to $R'$, or safe for short, if the following holds: If $R(V) \in A \setminus \{R\}$, then $R(V) \subseteq R'(H)$.

In other words, we say that a voting rule is safe (with respect to a base voting rule) if it elects a change to the status quo when applied to all voters only if the base rule may elect this change when applied to the genuine voters only. In this paper we are interested in studying safe voting rules (with respect to natural base rules). We are also interested in understanding whether and when they also provide for sybil liveness, as defined next.
**Definition 3 (Sybil Liveness).** Consider a set of voters \( V = H \cup S, H \cap S = \emptyset \), a set of alternatives \( A \), Reality \( R \in A \), and a voting rule \( R \). We say that \( R \) satisfies sybil liveness for \( V \) and \( A \), or liveness for short, if, for any set of votes of the sybils \( S \) and for any alternative \( a \in A \setminus \{R\} \), there is a set of votes of the genuine voters for which \( R \), applied to all voters, elects \( a \).

The above definition might be thought of with respect to a game played between the sybils and the genuine voters, where sybil liveness guarantees that, for any strategy of the sybils, there is a strategy of the genuine voters for which the proposal is chosen. To see the interplay between safety and liveness, consider the following example.

**Example 1.** The most obvious example of a safe voting rule is a voting rule which chooses as the winner the status quo, regardless of the votes. Indeed, as a proposal different from the status quo is never chosen by it, this voting rule indeed satisfies sybil safety. It is, however, obviously violates sybil liveness.

In this paper, our main goal is to investigate how to ensure sybil safety without being unnecessarily conservative in defending the status quo. We use the term sybil resilience to refer jointly to sybil safety and sybil liveness. The following definition captures a specific aspect of sybil resilience.

**Definition 4 (Sybil-Penetration Resilience).** We say that a voting rule \( R \) is resilient to the penetration of up to \( \sigma \) sybils, if it ensures sybil safety and sybil liveness for every set of voters \( V = H \cup S, H \cap S = \emptyset \), provided the sybil penetration rate is below \( \sigma \), namely \( |S|/|V| \leq \sigma \).

## 3 Sybil-Resilience for One Proposal

The case of sybil-resilient voting on a single proposal \( p \) (which, by default, is always against the status quo) is rich and interesting enough by itself. Hence, the focus of this section is on elections in which the voters vote yes/no on a single proposal \( p \), where a yes vote favors \( p \) and a no vote favors the status quo.

For this case, it is natural to use supermajorities as sybil-safe voting rules, and to use simple majority as the base voting rule against which sybil-safety is measured.

**Definition 5 (\( \delta \)-Supermajority).** In a vote on a proposal \( p \) against the status quo \( R \), the proposal \( p \) is said to win by a \( \delta \)-supermajority, \( 0 \leq \delta < 1/2 \), if more than \( 1/2 + \delta \) of the votes prefer \( p \) over \( R \). The proposal wins by a simple majority if it wins by a 0-supermajority.

**Remark 1.** Notice how the \( \delta \)-supermajority rule follows Reality-Aware Social Choice \([11]\) in inherently favoring the status quo.

**Definition 6 (Reality-aware \( \delta \)-Supermajority Rule).** When voting on a single proposal \( p \) against the status quo \( R \), the Reality-aware \( \delta \)-supermajority rule elects \( p \) if it is preferred over \( R \) by a \( \delta \)-supermajority, else it elects the status quo \( R \). The Reality-aware 0-supermajority rule is referred to as the majority rule.
It is clear that requiring a $\delta = \frac{1}{2}$ would render the Reality-aware $\delta$-supermajority rule sybil safe, as it would select the proposal only if all votes are in favor of it. As our aim is to ensure liveness while not being unnecessarily conservative, in the next theorem characterizes the minimal $\delta$ for which this rule is safe. It is stated for any two alternatives (not just $p$ and $R$ so as to be also useful for the general setting of multiple alternatives.

Lemma 1 (Safety of Supermajority). Let $V = H \cup S$ be the set of voters and assume that $|S|/|V| = \sigma \leq 1$ and let $p$ and $p'$ be two proposals. If $p$ is preferred over $p'$ by a $\sigma/2$-supermajority of all voters, then $p$ is preferred over $p'$ by a majority of the genuine voters.

Proof. Consider the equation:

$$\frac{1}{2} + \delta = \frac{\sigma + \frac{1}{2} \cdot (1 - \sigma)}{\sigma + (1 - \sigma)},$$

with the left side of the equation being the $\delta$-supermajority required for the majority of the genuine voters to vote for the proposal, assuming all sybils also vote for it, and the right side of the equation being the sybils ($\sigma$) and the majority ($1/2$) of the genuine voters ($1 - \sigma$), divided by the total voters, namely the sybils ($\sigma$) and the genuine voters ($1 - \sigma$).

Solving for $\delta$ gives $\delta = \sigma/2$, which proves the claim. \hfill \Box

Remark 2. Notice that the value $\sigma/2$ used in Theorem 1 is tight, in the sense that any value strictly smaller than $\sigma/2$ would not be safe. To see this, assume that all sybils, as well as half of the genuine voters, vote in favor of the first proposal.

Theorem 1 (Safety of Reality-aware Supermajority Rule). Let $V = H \cup S$ be the set of voters and assume that $|S|/|V| = \sigma \leq 1$. Then, the Reality-aware $\sigma/2$-supermajority rule is safe.

Proof. The Theorem follows directly from Lemma 1 and Definitions 2 and 6.

The following definition aims at quantifying the conservatism of a supermajority voting rule by investigating the situations in which the genuine voters can indeed change the status quo and cause the proposal to be elected.

Definition 7 (Supermajority Conservatism). Let $V = H \cup S$ be the set of voters and let $R$ be a Reality-aware supermajority voting rule. The conservatism $\rho$ of $R$ is defined as the supermajority among the active genuine voters needed in order to change the status quo, according to $R$, assuming all sybils vote in favor of the status quo.

The following observation gives a close formula for the conservatism of the Reality-aware $\sigma/2$-supermajority rule used in Theorem 1.

Observation 1 The conservatism of the Reality-aware $\delta$-supermajority rule, given a sybil penetration rate $\sigma$, is

$$\rho = \frac{\frac{1}{2} + \delta}{1 - \sigma} - \frac{1}{2}. $$
Proof. Let $V = H \cup S$ be the set of voters and let $|S|/|V| = \sigma$ and consider the Reality-aware $\delta$-supermajority rule where we have $\sigma n$ sybils, all voting in favor of the status quo and $(1 - \sigma)n$ genuine voters. Then, for a $\rho$-supermajority among the genuine voters, which is exactly $(1 - \sigma)n(1/2 + \rho)$ genuine voters voting for the proposal to change the status quo, they shall constitute at least a $\left(\frac{1}{2} + \frac{\sigma}{2}\right)$-fraction of the full electorate, which contains $n$ voters. Thus, solving the equation:

$$(1 - \sigma)n \left(\frac{1}{2} + \rho\right) = \left(\frac{1}{2} + \delta\right)n$$

for $\rho$ gives the result. \qed

Remark 3. Of particular interest is the special case $\delta = \sigma/2$, which, following Observation 1, implies a conservatism of $\rho = \frac{\sigma}{1 - \sigma}$. Notice that, e.g., if there are no sybils, then $\rho = 0$, which corresponds to a simple majority. On the other extreme, if a $1/3$-fraction of the voters or more are sybils, then $\rho > 1/2$, meaning that the proposal cannot be chosen even if the genuine voters are unanimously in favor of it, violating liveness.

Corollary 1 (Supermajority Liveness). Let $V = H \cup S$ be the set of voters and let $|S|/|V| = \sigma$. If all genuine voters vote, then the Reality-aware $\sigma/2$-supermajority rule satisfies sybil liveness if and only if

$$\sigma < 1/3$$

holds.

Proof. Following Observation 1, we have that $\rho = \frac{\sigma}{1 - \sigma}$. Solving $\frac{\sigma}{1 - \sigma} < 1/2$ for $\sigma$, which corresponds to at most a $1/2$-supermajority—which means unanimity among the genuine voters gives $\sigma < 1/3$. \qed

Corollary 2 (Supermajority Resilience). The $\sigma/2$-supermajority rule is resilient to the penetration of up to $\sigma = 1/3$ sybils.

Hence, we refer to a Reality-aware $\sigma/2$-supermajority, with $\sigma < 1/3$, as sybilresilient supermajority for short.

Remark 4. Notice that, as in Byzantine failures, a sybil penetration of $\sigma = 1/3$ is an inflection point with respect to a $\sigma/2$-supermajority. Up to $1/3$ sybils, a simple majority among the genuine voters can defend the status quo, i.e., veto a change to it, and a sufficiently large supermajority of the genuine voters may change the status quo. So the sybils can neither enforce a change nor veto it, if the genuine voters are sufficiently determined and united. However, above $1/3$ sybils, the sybils have a veto right; if the sybils unanimously object to a change, then no majority of the genuine voters can effect it. Hence, assuming $\sigma/2$-supermajority is our defense against sybils taking over the democracy in their favorable direction, then to avoid the other edge of the $\sigma/2$-supermajority double-edge sword, namely for a democracy not to be paralyzed by sybils, their penetration rate must be kept below $1/3$. 

6
4 Sybil-Resilience for Multiple Proposals

In this section we expand our investigation on Reality-aware sybil-resilient voting to elections in which the voters vote on multiple alternatives against the status quo. As mentioned above, we assume the ordinal model of elections, in that each vote is a ranking over the set of alternatives $A$ that includes the status quo $R \in A$.

Our approach for designing sybil-resilient voting rules for this setting is to follow the Condorcet principle and adapt it. Specifically, as in the section above we moved from a simple majority to $\delta$-supermajorities to ensure safety, here we move from simple majorities among the pair-wise comparisons considered in the Condorcet principle, to $\delta$-supermajorities. First we provide the following definition which will be used below: The set of $\delta$-viable alternatives contains exactly those alternatives which are preferred over the status quo by a $\delta$-supermajority.

**Definition 8 ($\delta$-Reality-viable Alternatives).** Let $S$ be a set of alternatives, $R \in S$ being the Reality, and let $\delta$ be such that $0 \leq \delta < 1/2$. An alternative $s \in S$ is \textit{$\delta$-Reality-viable} ($\delta$-viable for short) if $s$ beats $R$ by a $\delta$-supermajority. The set of $\delta$-viable alternatives is denoted by $S^\delta_R$. Note that if $\delta = 0$ then it can be omitted and a simple majority is used.

A $\delta$-supermajority Condorcet winner is similar to a Condorcet winner, albeit winning all pair-wise contests by a $\delta$-supermajority.

**Definition 9 ($\delta$-Supermajority Condorcet winner).** Let $S$ be a set of alternatives and let $0 \leq \delta < 1/2$. An alternative $s \in S$ is a \textit{$\delta$-supermajority Condorcet winner} if $s$ is preferred over any $s' \in S$, $s \neq s'$, by a $\delta$-supermajority.

Our approach follows the Condorcet principle as it is adapted to Reality-aware Social Choice [11]. Specifically, below we extend the various notions of Reality-aware Condorcet winners appropriately to accommodate for supermajorities. Specifically, next we discuss several Reality-aware Condorcet criteria adapted to our setting by employing $\delta$-supermajorities. Voting rules that adhere to these criteria follow in a straightforward way.

The Reality-aware $\delta$-Supermajority Condorcet criteria are different from the ordinary Reality-aware Condorcet criteria in employing a $\delta$-supermajority and $\delta$-Reality-viable alternatives. We discuss several definitions as they result in different voting rules differentiated by their degree of conservatism.

**Definition 10 (Conservative Reality-aware $\delta$-Supermajority Condorcet criterion).** Let $S$ be a set of alternatives with $R \in S$ being the Reality and let $0 \leq \delta < 1/2$. If $S^\delta_R$ has a $\delta$-supermajority Condorcet winner then elect it. Else elect $R$.

Notice that the above definition is conservative in that it allows changing the status quo only when a $\delta$-Condorcet winner among the $\delta$-viable alternatives exist. The next definition is less conservative as it allows changing the status quo whenever there is at least one $\delta$-viable alternative.
Definition 11 (Permissive Reality-aware $\delta$-Supermajority Condorcet criterion). Let $S$ be a set of alternatives with $R \in S$ the Reality and let $0 \leq \delta < 1/2$. If $S_R^\delta$ has a $\delta$-supermajority Condorcet winner then elect it. Else, if $S_R^\delta \neq \emptyset$ then elect an arbitrary member of $S_R^\delta$. Else, elect $R$.

Remark 5. Notice that the Conservative/Permissive Reality-aware 0-supermajority Condorcet criteria (i.e., for $\delta = 0$) are identical to the Conservative/Permissive Reality-aware Condorcet criteria [11]. All follow Reality-Aware Social Choice [11] in inherently favoring the status quo and utilizing it to sidestep Condorcet cycles. Indeed, this favoring of the status quo fits well with our first goal of safety of our voting rules against sybils.

The next theorem characterizes the minimal $\delta$ for which voting rules satisfying the above criteria are safe, where safety is defined with respect to certain base rules. These base rules correspond to the criteria and, for concreteness, are defined next. Note that $S_R$ is the set containing all alternatives which beat Reality $R$ by a simple majority.

Definition 12 (Conservative Reality-aware Condorcet Rule). Let $S$ be a set of alternatives with $R \in S$ be the Reality. If $S_R$ has a Condorcet winner then elect it. Else, elect $R$.

Definition 13 (Permissive Reality-aware Condorcet Rule). Let $S$ be a set of alternatives with $R \in S$ be the Reality. If $S_R$ has a Condorcet winner then elect it. Else, if $S_R \neq \emptyset$, elect all of $S_R$ as co-winners of the election. Else, elect $R$.

Next we use the Condorcet rules defined above as base rules for studying the safety of rules that satisfy the two $\delta$-supermajority Reality-aware Condorcet criteria defined earlier. Notice that Definition 10 and Definition 11 are concerned with sybil-resilience, as they incorporate $\delta$-supermajorities; these are the rules for which the next theorem shows safety. In contrast, Definition 12 and Definition 13 are not concerned with sybil resilience, and operate by simple majorities; indeed, below we use these rules as the base rules.

Theorem 2 (Safety of Supermajority Condorcet Rules). Let $V = H \cup S$ be the set of voters and assume that $|S| \leq \sigma |V|$ for some $0 \leq \sigma \leq 1$. Then: (i) Any voting rule satisfying Conservative Reality-aware $\sigma/2$-supermajority Condorcet criterion (Definition 10) is safe with respect to the Conservative Reality-aware Condorcet rule (Definition 12). (ii) Any voting rule satisfying Permissive Reality-aware $\sigma/2$-supermajority Condorcet criterion (Definition 11) is safe with respect to the Conservative Reality-aware Condorcet rule (Definition 13).

Proof. For claim (i), let $R$ be a rule satisfying the Conservative Reality-aware $\sigma/2$-supermajority Condorcet criterion and let $c$ be its winner in a given election. If $c = R$, then we are done as it is always safe to elect the status quo. Else, if $c \neq R$ then it follows that $c$ wins over each alternative in $S_R^{\sigma/2}$ by a $\sigma/2$-Supermajority and hence, by Lemma 1, $c$ wins over all these alternatives by a
simple majority among the genuine voters, and hence if there is a Condorcet winner among the genuine voters then it must be \( c \). Thus, the Conservative Reality-aware Condorcet rule would elect either \( c \) or \( R \), rendering \( R \) to be safe in this setting.

For claim (ii), let \( R \) be a rule satisfying the Permissive Reality-aware \( \sigma/2 \)-supermajority Condorcet criterion and let \( c \) be its winner in a given election. If \( c = R \), then we are done as it is always safe to select the status quo. Else, if \( c \neq R \) then it follows that \( c \in S_R^{\sigma/2} \), which implies, by Lemma 1, that \( c \in S_R \) when only genuine voters are considered. Hence \( S_R^{\sigma/2} \subset S' \), where \( S' = S_R \) as elected by Permissive Reality-aware Condorcet rule according to the genuine voters, implying safety.

The following observation gives a close formula for the conservatism of a Reality-aware \( \sigma/2 \)-Supermajority Condorcet consistent rule used above.

**Observation 2 (Conservatism of Supermajority Condorcet Rule)** The conservatism of a Conservative/Permissive Reality-aware \( \delta \)-supermajority Condorcet consistent rule, given a penetration rate \( \sigma \) of sybils, is

\[
\rho = \frac{1}{2} + \frac{\delta}{1 - \sigma} - \frac{1}{2}.
\]

**Proof.** Similar to Observation 1. \( \square \)

**Remark 6.** Similarly to voting on a single proposal, if there are no sybils, then \( \rho = 0 \), which corresponds to a simple majority. On the other extreme, if a \( 1/3 \)-fraction of the voters or more are sybils, then no alternative can be chosen over the status quo even if the genuine voters are unanimously in favor of it.

**Corollary 3 (Liveness of Supermajority Condorcet Rule).** Let \( V = H \cup S \) be the set of voters and let \( \sigma = |S|/|V| \). If all genuine voters vote, then a Conservative/Permissive reality-aware \( \sigma/2 \)-supermajority Condorcet consistent rule satisfies sybil liveness if and only if

\[
\sigma < \frac{1}{3}
\]

holds.

**Proof.** Similar to Corollary 1. \( \square \)

**Corollary 4 (Resilience of Supermajority Condorcet Rule ).** A Conservative/Permissive Reality-aware \( \sigma/2 \)-supermajority Condorcet rule is resilient to a penetration of up to \( \sigma = 1/3 \) sybils.

## 5 A Sybil-Resilient Condorcet-Consistent Voting Process

The section above concentrated on a normative and declarative approach to Sybil-resilience. Here we propose an efficient algorithmic realization of the supermajority Condorcet rules defined above. Our realization is based on the Amendment Agenda.
The Amendment Agenda was proposed by Ramon Llull in his 1299 *Des Artes Electionis* [7]: Arrange all alternatives in some order, vote the first against the second, the winner of the two against the third, and so on. Elect the final winner. It is known that the Amendment Agenda elects a Condorcet winner if there is one; it does not, however detect cycles.

Here we make four enhancements to the Amendment Agenda: (i) We consider only the $\delta$-Reality-viable alternatives; (ii) we start with the Reality $R$; (iii) we employ sybil-resilient supermajority; and (iv) at the end we check for a Condorcet top-cycle, and if one is detected – resolve it using Reality as the anchor.

**Algorithm 1 (Conservative $\delta$-Supermajority Amendment Agenda)** Let $S$ be the set of alternatives with $R \in S$, $0 \leq \delta < 1/2$, and $S^\delta_R$ be the set of $\delta$-viable alternatives. If $S^\delta_R = \emptyset$ then elect $R$. Else, perform a $\delta$-supermajority Amendment Agenda vote on $S_R$ starting with $R$, followed by extra votes of the final winner against all other members of $S^\delta_R$ not previously voted against, if any. If the final winner wins all these votes by a $\delta$-supermajority then elect it. Else elect $R$.

**Theorem 3.** Algorithm 1 satisfies the Conservative Reality-aware $\delta$-supermajority Condorcet criterion.

*Proof.* Let $S$ be the set of alternative with $R \in S$, $0 \leq \delta < 1/2$, and $S^\delta_R$ be the set of $\delta$-viable alternatives. If $S^\delta_R = \emptyset$, then the Agenda elects $R$ as dictated by the axiom. If $S^\delta_R$ is nonempty and has a Condorcet winner, then it will be the final winner, will beat all previous winners in the extra votes, and be elected as dictated by the axiom. If the final winner is not a Condorcet winner, then it must lose one of the extra votes, and $R$ will be elected, as dictated by the axiom. $\square$

**Remark 7.** An Amendment Agenda corresponding to the permissive $\delta$-supermajority Condorcet rule can be obtained by revising the final “Else” clause to be “Else arbitrarily elect a member of $S^\delta_R$.” The proof is similar.

### 6 Outlook

While a single fake voter may tilt election results in a majoritarian democracy, we show that Really-aware Social Choice can remain sybil-safe in the face of arbitrarily high sybil penetration, and can retain sybil-liveness in the face of up to one third sybil penetration. We presented a simple and efficient sybil-resilient Reality-aware Condorcet-consistent voting process.

Throughout this paper we have assumed full voter participation. A companion paper [10] explores sybil-resilience in the face of partial participation by the genuine voters.
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