Ethelo

An Algorithm-Based Approach for Resolving Complex Group Decision Problems Fairly

Abstract

Many of society's most intractable problems, such as climate change, income inequality and military aggression, can be traced at some point to a failure of collaborative decision-making. While finding solutions is of broad general interest and the focus of much economic and technological activity, the intractable problem is often finding agreement on sharing the costs of the solutions. These are group decision problems, and solutions could be realized - if we had group decision processes that were sufficiently effective. Conversely, these problems are highly resistant to being solved using the same decision making processes that led to them in the first place. Concentrations of power, factional division, paralysis, lack of accountability and disengaged citizens are only some of the reasons why things seem to be stuck in place..

Democracy as it now stands is not the answer. The complex challenges of modern society require fundamentally new approaches to governance and group decisions. Ethelo is an attempt to provide a new framework for group decision-making and participatory democracy that could address these challenges.

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Ethelo Theory

“Ethelo” is a word from ancient Greek that means “intention” or “willpower.” The theory underlying ethelo is that complex problems can be solved by identifying decisions that will focus the disparate intentions of unique individuals into single unified collective intention and action.

Ethelo theory treats each participant’s latent desires as a quantifiable energy that can be modelled across different decision scenarios. An ideal group decision, in this approach, is one in which the greatest amount of intentional energy is harnessed from the group. Importantly, in identifying an outcome that attracts the greatest support, ethelo theory does not simply sum the individual levels of satisfaction but also looks to emergent factors such as fairness or inequality in the distribution of that satisfaction.

A “strong” decision in ethelo theory is one that optimizes the available intentional energy by looking at both individual as well as collective factors such as fairness. Such decisions are “efficient” in ensuring that the greatest amount of potential intentional energy is conserved in the transition from the individual to the collective.

A Theory of Fairness

Ethelo theory is based on the work of John Rawls, a 20th century philosopher and social contract theorist. Rawls wrote about the importance of fairness in democracy. He devised a number of thought experiments such as the famous original position in which everyone is impartially situated as equals behind a veil of ignorance as they negotiate the social contract.

Central to Rawls’ thinking was the balance that must be struck between personal satisfaction and ideas of fairness rooted in the distribution of satisfaction. As a matter of first principle, he argued, everyone will accept some degree of inequality if it means we do better collectively as a result - “a rising tide raises all boats.” Rawls’ conclusions about the degree of acceptable inequality, and how to strike the balance, have been the topic of much argument since. However, his basic framing of the social contract is an enduring legacy and has been described as the most important work in 20th century political philosophy.

Rawls' "Theory of Justice" was published in 1971, and "Justice as Fairness" was published in 1985. His philosophical intuition on the importance of fairness has since been validated empirically in the social sciences under the general heading of "social preferences" and "inequity aversion." Studies show that people will reject unfair outcomes even when they would otherwise benefit. Likewise, they will support outcomes they dislike if the process was seen as fair. This powerful phenomenon has been documented in both human and animal experiments.

Ethelo is a practical solution to the philosophical and social challenge of making group decisions that balance individual factors and collective factors such as inequity aversion.

Morphological Analysis

Morphological analysis, which means "the study of forms" is well established as a method for modelling structural relationships between objects and phenomena in a number of scientific fields including botany, linguistics, geology and mathematics as well as social problems including forecasting, defence planning and political problem-solving. A generalized version of the method was originally proposed by Swiss-American physicist and astronomer Fritz Zwicky (1898–1974).

Strong similarities in the basic conceptual framework between Ethelo theory and morphological analysis place them in the same family of analysis. However, Ethelo theory was developed independently and contains several concepts not found in any morphological framework. It is perhaps best framed as an extension of morphological analysis. A fuller exploration of the differences and similarities is set out in Appendix 1.

The Space of Possibility

Ethelo theory imagines, for each decision, that there is a "space" that contains all the possible outcomes for that decision. Each potential outcome is like a point in this space. For example, we might imagine the space is like the surface of a table; outcomes that are similar would be closer together on the table, outcomes that are dissimilar are far apart. Note this may be a misleading example as the space of conceivable possibility is more like an n-dimensional network than a continuous two-dimensional space. But it is imaginable and mathematically possible to find some projection on a two-dimensional space like a table.

Over this flat table of potential outcomes, image a rolling hillside. This hillside is a function (the "influent function"), which represents a person's support for each of the potential outcomes. That is, for each outcome (= point on the table), the height of a participant's influent function (= the rolling hill) represents the amount of support they would have for that outcome. If the function over a point is high, the support for that option is high, and conversely, low.

Making a collective decision, then, is a matter of performing an operation that integrates the individual influent functions across the group to find a specific outcome that will optimize the support of all the individuals.

Modelling Intention

Ethelo uses web-based tools to gather information that allow us to model the influent function of each participant. Rather than trying to gather information about each potential outcome (generally impossible as there can be millions in complex decision) we can represent a complex decision as a much smaller set of key sub-decisions. We use these web tools to measure a participant's response to the sub-decisions, and use that information to extrapolate their level of support for all the outcomes. The Ethelo toolset gathers information on the different decision-junctures in the overall evaluation process.

Ethelo takes the approach that the preferences of a group can be represented in the same way as that for an individual; as a influent function over a space of outcomes.

Optimizing Collective Energy

The "collective" influent function is created by aggregating the individual individual functions in a way that balances individual factors (such as personal satisfaction) with collective factors (such as fairness in the distribution of satisfaction). In this way, Ethelo incorporates the thinking of John Rawls and the importance of fairness.

What makes Ethelo unique is that support for a potential outcome is viewed, not just as the sum of the various individuals' support for that outcome, but also as deeply dependent on the distribution of support for that outcome. If the support is highly polarized, then there will be internal resistance to execution of the decision and it will be a "weak" decision. That is, the "intentional energy" behind a polarizing outcome will reduced as a result of the polarization. On the other hand, if people in a group experience similar levels of support for an outcome, then it will be perceived as fair and the resulting intentional energy will increase (or decrease) due to the unity of sentiment.

Ethelo Stated Simply

Stated simply, Ethelo is a prioritization algorithm. It takes a set of the characteristics of all the potential decisions — which can be very large, limited only by the imagination — and distills that set down to a much smaller, internally consistent set of characteristics which describe a single decision scenario. If the process is successful, that resulting single decision is one that most effectively optimizes the available energy from the participants to render decisions that have broad levels of support across a constituent base..

THE ETHELO PROCESS

The Ethelo process divides into three stages,

1. Ideation
2. Voting
3. Aggregation

The final result of a Ethelo process is an “outcome,” which is chosen from a ranked set of potential outcomes called “scenarios.”

These three stages will be explained below with references to an example problem: the challenge of developing an international treaty. We chose the development of a “Treaty of Interpretation” for the United Nations’ proposed Crime of Aggression. A three-minute video which gives a quick summary of the example can be found at www.ethelo.com/videos

I. IDEATION

Ideation here refers to defining the potential components of group decision to be made. These elements include the underlying issues, options, constraints, and criteria that the Ethelo algorithm will use to create the online collaboration environment, the corresponding web tools, and the space of potential scenarios that this environment and tools will be used to explore.

1. Issues

“Issues” refer to a general breakdown of a decision topic into subtopics. Issues can be thought of as buckets within which specific proposals or “Options” are contained. For example, Issues might correspond to the chapters or sections in a treaty. If the treaty were aimed at clarifying what constitutes a Crime of Aggression, for example, the Issues might be “Cyber Warfare,” “Armed Aid,” and “Counter-Terrorism.”

There is no limit to the number of issues Ethelo can accommodate, except the practical limit of time required for the evaluation

2. Options

An “option” is a specific action, or policy, which can be implemented as a part or facet of an overall decision. They are not whole decisions in themselves, but discrete and possibly abstract components that are candidates for describing some aspect of a final decision. “Options” are categorized as “belonging” to an Issue.

In the Crime of Aggression example, options under the Issue “Cyber Warfare” might including specific policies such as “Planning and Preparing a Cyber Attack,” and “Aiding and Abetting a Cyber Attack,” Options can be described with varying levels of abstraction, from a title consisting of a few words, to a short summary, to a detailed description which might include supplementary materials.

NOTES:

- If there is disagreement about what Options should belong to which Issue, the Ethelo algorithm can support each participant having their own, unique organization of Options into Issues.

- From a procedural perspective, it may be preferable in some cases to start with an exhaustive list of proposed Options, and then develop a structure of Issues which categories them in a sensible way. The end result is the same.

- In some cases, the list of Issues is so long that it is difficult to work with. In that case, it is possible to impose a second or even third level of organization, where Issues are grouped into “Categories” and Categories grouped into “Chapters.” The naming convention is not important; the point here is that Ethelo supports hierarchical nesting of Issues.

In practice, Options are often determined — or at least approved —by a decision-maker who carries final authority. However, the ideas which become Options can come from anywhere and it is usually a good idea to cast a wide net. The Ethelo platform can be configured to allow participants to propose “suggestions” which can be converted to Options by a decision-maker.

Options are the building blocks of decision-making. An Outcome or Scenario can be expressed as some combination of Options.

2a. Characteristics

Each Option can be associated with a set of measurable, quantitative "characteristics" which further define the Option. For example, an Option might have a financial cost; an amount of money to execute the Option. Characteristics can be relatively abstract, such as the "feasibility" or "benefit" or "difficulty" of an Option; as long as they can be expressed as a quantity.

Along with discrete characteristics such as cost, Options can also be assigned continuous characteristics that change according to other characteristics. For example an option "rice" may have a characteristic "quantity," and another characteristic "price",,where price varies continuously relative to quantity.

If we define characteristics for Options in a decision, it naturally follows that a Scenario can also have characteristics, determined by the Options that comprise that Scenario. We can further create new kinds of Scenario Characteristics which are based on relationships between Option Characteristics. For example, if Options have both a "cost" and "revenue" characteristic, then a Scenario could have a "total cost" characteristic, which is the sum of the cost of each option (in the Scenario) minus the revenue of each option (in the Scenario)"

3. Constraints

Constraints are rules which limit which Options can appear together in a decision outcome. Constraints can be of various types;

- Logical Constraints

Logical constraints refer to relationships between Options that can be described using boolean logic. For example, "exclusions" where two Options cannot appear together in a decision outcome, either for logical or practical reasons. In the Crime of Aggression example "Air Pollution is not a Crime of Aggression" and "CO2 Emissions are a Crime of Aggression" would be two exclusionary relationships; both Options cannot appear in the same treaty without creating an internal contradiction. Other logical relationships include necessary (B therefore A) and sufficient (A therefore B).

- Set-based Constraints:

It some cases, arriving at a decision will require choosing a discrete number of Options from a set of Options. For example, if we are to decide which individuals will compose an elected body participants may vote on different proposed sizes for the body, and also vote on the various candidates who are nominated. Assuming there are many candidates, a set-based constraint would ensure that the Ethelo process returns (a) the size of the body and (b) a list of candidates. The set-based constraint in this case would ensure that the number of candidates on the list is the same as the approved size of the body. Ethelo supports set-based constraints such as "equals" "less than" "greater than" between # and #". Scenarios for which these set-based constraints are not met would be excluded.

The list of Options which are the inputs to an Ethelo process can be divided into any number of overlapping or non-overlapping sets, each of which can be subject to its own set-based constraints.

- Calculated Constraints:

The Ethelo process allows the identification of decision outcomes which must obey quantitative restrictions such as budget, etc. These Calculated Constraints are generally tied to one or more Outcome Characteristics. A Calculated Constraint is defined by creating a boundary condition that is used to determine whether a Scenario is valid. Boundary conditions are expressed as relations, for example "total cost < total budget" which are true or false for any given Scenario. Combinations of options for which the Boundary conditions are not met are excluded from the set of potential Outcomes.

Similar to above, characteristics and boundary conditions can be subject to the Ethelo voting process.

4. Criteria

"Criteria" refer to frameworks of evaluation, or values, that will be applied by Participants to the different Options. These Criteria are expressed as polarities that translate to a numeric range, generally the range of [-100, 100] or [0, 100]. The default criteria is simply "Oppose v. Support", where "totally oppose" equals

-100 and "totally support" equals 100. This numeric range can equivalently be expressed as a [-1, 1] or [0, 1] range.

Often a single criteria is used to evaluate Options. However, multiple criteria can also be used. A set of multiple Criteria that might also be relevant to Options in the Crime of Aggression example might be "Unenforceable v. Enforceable" "Inexpensive v. Expensive" "Negative Social Impact v. Positive Social Impact".

Each participant can identify a set of criteria or objectives that they wish to apply in evaluating the Options. Different Criteria may be used with different Options or Issues. Participants can select as many criteria as they wish, and these criteria do not need to be shared with other participants.

NOTE: In some cases, it may be useful to group Criteria into "meta-criteria". Similar to MCDM (Multi-Criteria Decision-Making) tools, Ethelo supports hierarchical nesting of Criteria.

II. VOTING

The ideation process described above is a creative, non-competitive one; while some decisions needed to be made, it is basically a generative process that prioritizes inclusion of options. The following stages (Voting and Evaluation) describe the convergent aspect of Ethelo where it uses evaluative and algorithmic tools to reduce the very large set of possibilities down to a single, optimal group decision.

The goal of voting in the Ethelo process is to create an "Influent Function" for each Participant. An Influent Function is simply a set of scores, one for each of the Options. If there are 5 Options, then each Participant will emerge from the voting process with a "vote" in the form of a set [a,b,c,d,e] where a, b,c,d,e are each numbers corresponding to an Option.

Ethelo allows two types of voting.

Direct Voting

The Ethelo direct voting process consists of each participant assigning some quantitative scores to Options, via the the application of a set of Criteria and a weighting of the Issues.

1. Evaluating Options

Each participant evaluates each Option by assessing, in their opinion, how well the Options stand under the application of one or more Criteria, on a scale [-100 to 100]. In this system, "-100" means that the Option falls on the negative pole of the Criteria, "0" means it is neutral, and "100" means the Option falls on the positive pole of the Criteria. Options will generally fall somewhere on the spectrum between the two extreme poles.

This [-100,100] scale can be simplified as a series of buttons, representing different points on the scale. For example, five buttons might correspond to the values of [-100, -50, 0, 50, 100]. In the Crime of Aggression example, nine buttons are using corresponding to the values of [-100, -75, -50, 25, 0, 25, 50, 75, 100]. However many buttons are used is not important - Option voting can also be done using a sliding scale to allow any number to be selected.

A participant's evaluation of an Option can be expressed as a set of scores under each Criteria, called a "Criteria Score." For example, the Option "Aiding and Abetting a Cyber Attack," when evaluated under the three Criteria "Enforceability," Cost" and "Social Impact," might result in a Criteria Score of [10, -10, 50].

2. Weighting Criteria

If only one piece of Criteria is used to evaluate Options, there is no need to weight it. However, if more than one Criteria is used, it will be necessary to assign relative weights to the Criteria on a scale of [0, 100]. These weights will be used, along with the Criteria Score, to assign an "Raw Score" to that Option for the Participant.

This is best illustrated with an example: the three Criteria "Enforceability," "Financial Cost" and "Social Impact" described above might be assigned weights [20, 50, 40] respectively by the Participant. In that case, the "Aiding and Abetting a Cyber Attack" would receive a Raw Score from the Participant of [10x20 + -10x50 + 50x40] = [200-500+2000] = 1700.

3. Weighting Issues

Along with weighting Criteria, each participant might also assign a weight to each Issue, on a scale of [0, 100] indicating the importance of that Issue to the Participant. This weight is used, in conjunction with the Raw Score, to define an Overall Score to the Option for the Participant.

For example, the Issues "Cyber Warfare", "Armed Aid", "Counter-Terrorism," might receive weightings [50, 10, 75] by the participant. If "Planning and Preparing" and "Aiding and Abetting" were Options under the Issue "Cyber Warfare," and received Raw Scores of 20 and 15.45 respectively, then after the Issue weighting the Overall Scores would be [20x50] and [15.45x50] = 1000 and 772 respectively.

Note: As note above, Criteria can be nested, so that a meta-Criteria {A, B, C} may actually refer to a longer list of Criteria {a1, a2, a3, b1, b2, b3, c1, c2, c3 etc} where the Criteria can be applied and weighted, and the meta-Criteria can also be weighted. The same is true of Issues.

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Through the above process, each participant will have assigned each option an Overall Score which will be some positive or negative number. So, if there are 20 options, the participant's "vote" would be a series of 20 Overall Scores, each Overall Score corresponding to one of the Options. This series of Overall Scores will be referred to as the pre-normalized "Influent Function" of the Participant.

Trust Voting

Ethelo allows an advanced form of liquid democracy, in which rather than voting directly on Options and Issues, Participants can choose other Participants they trust, and define their Influent Function by specifying how much they trust those Participants. Ethelo will then construct an Influent Function on their behalf drawing from the Influent Functions of those trusted Participants.

Ethelo allows participants to be very specific and granular about the distribution of their trust. Participants can specify how much they trust each person's expertise, not only with respect to different decisions but also with respect to the application of different Criteria and the understanding of different Issues in those decisions.

This “trust-based” approach allows Participants to engage intelligently in decision-making processes without being experts in the substance of the decision at hand, but rather by relying on social factors such reputation, relationships, statements, and shared connections. People are extremely effective at reaching conclusions about trust based on social factors.

Current models of representative democracy rely heavily on this wisdom, but it is undermined by the highly concentrated and general power of the representatives they elect. Ethelo allows the selection of many and diverse experts, and allocations of influence to those experts in a much more granular and directed manner.

1. Assigning Trust

Ethelo allows a Participant undertaking Trust Voting to identify a group of Participants, {p1, p2,...,pn} and assign a “trust ranking” to each of those participants on a scale of [0, 100] corresponding to how much they are trusted by the Participant with respect to the decision at hand. Using this information, Ethelo can construct an Influent Function for the Participant by merging the trusted Participants’ Influent Functions.

For example, if a given Participant Pat assigns three other Participants {p1, p2, p3} a trust factor of [40, 10, 70] respectively, then Ethelo can define a new Influent Function for Pat using vector addition; IF(Pat) = 40*IF(1)) + 10*IF(2) + 70*IF(3), where IF(1) = the Influent Function of Participant p1, etc.

2. Assigning Trust wrt different Issues

In the above, Participants indicated a general level of trust for other Participants. However, Ethelo also enables a Participant to create their Influent Function by specifying how much they trust the opinion of other Participants with respect to different Issues.

For example, a Participant may trust Participants p1, p2, p3 on the Issue of Cyber Warfare to an extent of [20, 30, 50] respectively. If those three Participants gave Overall Option Scores [.3, .5, .2] to the Option

“Planning and Preparing”, then Ethelo would attribute an Overall Score of [20 *.3 + 30 * .5 + 50 *.2] = 31 to the Participant for the “Planning and Preparing” Option.

There will still be a need for the Participant to assign a weight the respective Issues. The Participant can do that themselves, or use the Trust methodology to arrive at a weighting based on the weightings assigned by any or all of the Participants above, using weighted averages.

3. Assigning Trust wrt different Criteria

Ethelo further enables a Participant to create their Influent Function by specifying how much they trust other Participants in the application of different Criteria.

For example, a Participant may trust Participants p1, p2, p3 on the application of the “Enforceability” Criteria, to an extent of [50, 20, 40] respectively. For clarity, consider that a Participant’s “Criteria Score” is a set of scores (vector), like an Influent Function, but restricted to the application of a particular Criteria to the Options. Ethelo can then draw from the Enforceability Criteria Scores of Participants p1, p2 and p3 to define a new Enforceability Criteria Score for the Participant equal to [50 * ECS(1) + 20 * ECS(2) + 40 * ECS(3)], where ECS(1) is the Enforceability Criteria Score of participant p1 etc.

There is still a need for the Participant to assign a weight the respective Criteria. The Participant can do that themselves, or use the Trust methodology to arrive at a weighting based on the weightings assigned by any or all of the Participants above, using weighted averages.

Democratic Equality

In a traditional democratic voting process such as majority vote or proportional representation, each participant is meant to have an equal influence. This “democratic principle” is observed by giving each person one and only one vote. However, often participants whose candidates lose in such processes find themselves with much less influence on the final result than participants whose candidates win. Thus, the appearance of an equality of influence disguises a structural inequality: there are winners and losers.

Ethelo avoids the failure of traditional voting methods which allow winners and losers to have different levels of influence. It does this using a variety of methods. One of those is by using a normalization step described below.

Normalization

The mathematical impact each participant has on the Ethelo aggregation process (described below) is determined by the sum of the absolute values of the Participant's Option Scores. This is the "mathematical pressure" they are able to exert on aggregation process.

Therefore, in order to ensure a fair distribution of influence across the Participants, each Participant's Influent Function can be normalized, so that the sum of the Option Scores in their Influent Function is equal to 1. In many cases, this can be done by dividing each of the Option Scores by the sum of the absolute values of the Participant's Option Scores. For example, if a Participant's Influent Function is expressed as [-40, 35, 600, 21] then the divisor would be [40 + 35 + 600 + 21] = 696. The Normalized Influent Function would then be: [0.057, 0.05, .82, 0.03].

A slightly more complex normalization process using exponents is used in the Ethelo algorithm, due to competing objective of having all Option Scores be less than or equal to one for the purposes of Aggregation below.

Influence

After normalization, the Influent Functions of each Participant will have equal influence on the aggregation process.

Although democratic ideals often require the equality of influence, it is not always the case that equality = fairness. Sometimes, people are affected differently by decisions, or they may have different rights to participate in decisions due to pre-existing agreements or entitlements. In those cases, it is important to support non-equal distributions of influence in decisions.

Ethelo allows the non-equal distribution of influence among participants in decision-making quite simply, by multiplying Participants' normalized Influent Functions by some factor representing the amount of influence they should have in the process.

For example, if a Participant p1 is entitled to 4x as much influence as Participant p2 , then Ethelo can respect this agreement by multiplying p1's normalized Influent Function by 4.

Representative Accuracy

The ability to define levels of Influence makes Ethelo capable of ensuring equitable, representative outcomes even when participants in a given process are not representative of the larger population.

This demographic-corrective capability (when enabled) works as follows: For example, if 20 percent of the participants in a Ethelo process belong to a minority group, but that minority group comprises 30 percent of the population, Ethelo can increase the influence level of members of that minority group by 1.5x. The Influence level of other participants can also be adjusted to represent their true prevalence in the population. In this way, a non-representative vote sample can be corrected to show representative results.

III. AGGREGATION

As a result of the Voting process, each participant is associated with an Influent Function which has been normalized and adjusted as needed. The Ethelo algorithm will aggregate these Influent Functions by using them to evaluate a space of potential decisions scenarios, as follows:

1. Generating Scenarios

We define a "Potential Scenario" as some combination of Options, without regard to whether the Options are consistent with each other. We can express a Potential Scenario as a series of 1s and 0s, where "1" means an Option is present, and "0" means it is absent. For example, if we are dealing with a Decision that includes three Options in an ordered sequence Option 1, Option 2, Option 3, and Option 4 then, we can express every Potential Scenario as a series of four 1s and 0s, where "1" means an Option is present in the Scenario and 0 means the Option is not present. So, Potential Scenario [1, 1, 0, 0] would consist of Option 1 and Option 2, but not Option 3 or Option 4.

We can see that if there are four Options, then there are 2^4 = 16 Potential Scenarios. If there are 20 Options, then there will be 2^20 = 1,048,576 Potential Scenarios. It is clear that the space of Potential Scenarios can get very large if there is a significant number of Options.

Ethelo refines" the set of Potential Scenarios down to a set of Actionable Scenarios (or simply "Scenarios") by ensuring that each Scenario obeys the Constraints. For example if there is a constraint that Option 2 and Option 3 are mutually exclusive (cannot logically exist together) relationship, then Ethelo will eliminate any Scenarios of the form [n, 1, 1, n] where "n" could be either 1 or 0.

For Ethelo, generating the set of Scenarios means eliminating any Potential Scenarios that fail to comply with the various types of Constraints.

2. Scoring Scenarios Individually

A "Scenario Score" given by a Participant to a Scenario is calculated by combining the Option Scores in some way. Usually, that combination is done using simple addition. For example, if a Participant's Influent Function for a Decision consisting of four Options is [0.2, 0.3, 0.1, 0.4] then the Participant's Scenario Score for Scenario [1,0,1,1] would be 0.7.

While adding Option Scores is the obvious approach, the satisfaction derived from an Outcome is not always simply the sum of satisfaction derived from the component Options. In some cases, the Scenario Score is better calculated using the average Option Score ("quality is better than quantity"). In others, the Option Scores will be multiplied by a Characteristic, such as cost, before being added together to reflect the greater value of more expensive Options.

- Real-Time Feedback

Ethelo is able to evaluate all the Scenarios using a Participant's vote information and corresponding Influent Function, and return their top-scoring Scenario in real-time. This "Top Choice" feedback enables a Participant to adjust their scoring, weighting and trust allocation to ensure that the Influent Function they are creating is aligned with their intention. For example, there may be constraints that restrict the potential Scenarios so that it is impossible for Participants to achieve their perfect Scenario. Ethelo allows participants to interactively optimize within these constraints, by adjusting the various voting tools (option scoring, criteria weighting, issue weighting, trust assessments, etc.) until their favourite (if still imperfect) outcome appears in the "My Top Choice" panel.

4. Evaluating Scenarios Collectively

Ethelo is able to aggregate the Influent Functions of all the Participants to find the best "group decision." It does this by evaluating each Scenario and assigning it a variety of metrics, the primary ranking metric being the "Ethelo Score" as described below. It is then able to present the best Scenarios in ranked order from the strongest group decision to the weakest group decision.

The defining aspect of Ethelo's aggregation methodology is that it looks not only at the average level of support for a scenario across a group, but also at the distribution of that support. Ethelo incorporates research from sociology and game theory that shows that similarity in levels of satisfaction, aka fairness, is a key determinant in the strength of group decisions.

Definitions:

a. Support ≈ Influence = "I"

Support is the AVERAGE Scenario Score that a group of Participants give a Scenario.

- Note: One key aspect of the theory underlying Ethelo's approach is that support can be analogized to influence. Ethelo looks at the scoring process as a way for participants to distribute their influence across the spectrum of possible outcomes. For this reason, Support is referred to as "I" in the below equations.

b. Approval

Approval is the percentage of group Participants whose score for a given Scenario is positive (greater than zero).

c. Dissonance = DS

Dissonance refers to the variance (in mathematical terms) of the distribution of support for a Scenario. It is referred to as "DS" in the equations. On the platform, it is sometimes called "Conflict." It can be also expressed as standard deviation, or any of number of measures of variance in distribution.

Dissonance falls in the range of [0, 1]

If every Participant gives a Scenario the same Scenario Score, then Dissonance = 0. If a group is completely polarized, in which half completely oppose a Scenario (Scenario Score =1) and half completely opposed the Scenario (Scenario Score = -1) then Dissonance = 1.

d. "Tipping Point" = t

Research in behavioural economics and social psychology has found that "inequality aversion" will cause group Participants to reject Scenarios where satisfaction is distributed unfairly. Even Participants who benefits from unfairness have been found to show less support for unfair outcomes. Conversely, group decision participants will show more support for Scenarios where satisfaction is distributed fairly. Even Participants who personally dislike an Outcome will show increased support for the Outcome if satisfaction is distributed fairly across the Participants.

Ethelo incorporates this phenomenon in its evaluation of what constitutes a strong decision. Framed in mathematical terms, as DS for a Scenario decreases from 1 to 0, there will be a "tipping point" when people will cease to resist the outcome because of inequality aversion, and begin to support it due to fairness and the unity it creates. Where this neutral tipping point is found will depend on the type of decision process and group dynamics, and can be determined empirically or by mutual agreement.

A priori, we can take "t" as the dissonance of the support distribution in which there are an equal number of participants at each possible level of support, that is, where the distribution graph is completely random. This distribution curve of support will be flat over all possible levels of support. In that case, we can take t = 1/3 which is the integral of the variance over that flat distribution.

e. Unity = U

Unity is a measure of the internal cohesion of a group wrt a Scenario, due to fairness in the distribution of support for that Scenario.

U can range from negative, when a group is polarized in its feedback (high Dissonance), to positive when a group is unified (low Dissonance). We take the tipping point "t" as the neutral mid-point where a group is neither polarized nor unified; U = 0.

Define U: some function mapping DS onto a range {-1, 1}, where U(1) = -1, U(0) = 1, and U(t) = 0, t is the "tipping point"

We define U as follows:

If DS <= t then U = (t-DS) / t, U falls in [0,1]
If DS >= t then U = (t-DS) / (1-t), U falls in [-1,0]

f. Fairness = F

Unity has a different relevance in different decision contexts. This is because the phenomenon in which a decision becomes stronger through group unity is a social phenomenon; it ceases to have meaning if there is only one participant. For example, in a process where participants do not have relationships or the sense of reciprocity that arises in community, it may not be important that they experience similar levels of support for a Scenario, or feel that influence in shaping the outcomes should be distributed fairly. However, in a stakeholder process where there are entitlements based on a mutually agreed-upon social contract, then fairness in the distribution of support for a Scenario can be quite important.

Fairness "F" represents the importance of Unity in a specific decision context, and falls in the range [0,1].

Fairness can be determined by enabling each Participant to identify what they feel is an appropriate level of fairness. This can be done interactively by allowing them to adjust a distribution curve to find their optimal trade-off between Support and Unity. From that, an average Fairness can be found, perhaps modified by any Influence factor.

g. Strength = Ethelo Score = $\in$

In Ethelo theory, “Strength” refers to the collective intentional energy available for execution of a Scenario as a decision. In a group context, the support of individuals treated in isolation is not sufficient to determine the strength of a group decision, because of the impact of unity or the lack thereof. Conversely, unity alone is not sufficient to determine the strength of a decision, because people can be highly unified in opposition as well as in support.

The Ethelo Score combines the factors of Support, Dissonance, the Tipping Point, Unity, and Fairness into a single function that observes the following Axioms.

Ethelo Axioms

1. If I is constant, $|\in|$ will increase as U increases, and decrease as U decreases
2. If U is constant, $|\in|$ will increase as $|I|$ increases, and decrease as $|I|$ decreases
3. $\in$ must carry the same sign (positive or negative) as I
4. if $U = 0$ then $\in = I$,
5. if $U > 0$ and $F > 0$ then $|\in| > |I|$
6. if $U < 0$ and $F > 0$ then $|\in| < |I|$
7. if $U = -1$ and $F = 1$ then $|\in| = 0$
8. If $U = 1$ and $F = 1$ and $|I| \neq 0$ then $|\in| = 1$
9. If $I = 0$ then $\in = 0$
10. increasing F increases impact of U on $\in$

Taking the above Axioms, we can define the Ethelo Score as follows:

If $I > 0$ and $DS < t$, then depending on the value of F, $\in$ will fall somewhere in range of $[I,1]$

We can define $\in = I + F * U * (1-I)$

$$\in = I + F * (t-DS) * (1-I) / t$$

If $I > 0$ and $DS > t$, then depending on value of F , $\in$ will fall somewhere in range of $[0,I]$

We can define $\in = I + F * U * I$

$$\in = I + F * (t-DS) * I / (1-t)$$

If $I < 0$ and $DS < t$ then depending on the strength of F, $\in$ will fall somewhere in range of [I,-1]

We can define $\in = I + F * U * (-1-I)$

$$\in = I + F * (t-DS) * (-1-I) / t$$

If $I < 0$ and $DS > t$ then depending on the strength of F, $\in$ will fall somewhere in range of [0,I]

We can define $\in = I + F * U * I$

$$\in = I + F * (t-DS) * I / (1-t)$$

Simplifying the Ethelo Calculation

We can define $\in$ generally:

$$\in = I + F * (t-DS) * K$$

Where if $I > 0$ and $DS < t$ then $K = (1-I) / t$

Where if $I > 0$ and $DS > t$ then $K = I / (1-t)$

Where if $I < 0$ and $DS < t$ then $K = (-1-I) / t$

Where if $I < 0$ and $DS > t$ then $K = I / (1-t)$

Ethelo in Practice

Using the above approach, the Ethelo algorithm is able to identify, score, and rank Potential Scenarios according to the likelihood that those decisions will receive the strongest support of a group.

The Ethelo algorithm is challenging to compute using brute force, due to the exponential growth of Scenarios as decision get more complex. For example, if there are 30 options, then the number of

Potential Scenarios is 2^30 = 1 billion. 40 options requires the analysis of 1 trillion scenarios and 100 options requires the evaluation 1.26*10^30 scenarios. Even today's powerful computers will be challenged by the task of analyzing so many scenarios to provide participants with real-time feedback on their Top Choice.

Therefore, for complex decisions the Ethelo Objective Function is solved using nonlinear optimization techniques, written in C++ for the fastest possible calculation. While this approach is not provably complete (that is, it cannot be proven that it will find the "best" decision), it is highly optimized and a number of heuristics are used to provide resistance to errors due to local minima.

Appendix 1

Ethelo and Morphological Analysis

Morphological analysis (MA) allows a decision space to be expressed as a set of issues, each of which contains a set of options. Each potential decision outcome is expressed as a set of options containing one option from each issue. It is therefore associative, mapping n options to a space of x1*x2*...*xn potential outcomes where xi is the number of options in issue i. This one-to-many mapping sets MA apart from bijective systems such as MCDM (multi-criteria decision-making) which maps n options to a space of n potential outcomes.

Constraints in MA are expressed as XOR (either-or) relations between options, which defines a test to determine whether outcomes are valid. Outcomes which contains option in an XOR relationship to each other are invalid.

Ethelo theory contains several elements which are not found in MA. Ethelo theory;

- Allows multiple criteria to be applied in the evaluation of options, and weighting of different criteria and issues
- Extends the concept of outcomes from one-option-per-issue to any number of options per issue, along with a more generalized concept of constraints (not merely XOR) with global variables and boundaries. Therefore, the size of potential outcomes in Ethelo theory is not x1*x2*...xn, but 2^n.
- Enables option evaluations by multiple participants with different levels of influence and provides a method of integrating those evaluations that can accommodate ideas of fairness. MA is one-person.

Morphological analysis can be represented as a constrained subset of Ethelo theory.