

**UNIVERSITATEA POLITEHNICA BUCURESTI**  
**Facultatea de Automatica si Calculatoare**  
Departamentul de Calculatoare



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**Integrated Decision Making Environment**

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Conducator Stiintific:

*Prof. dr. ing. Nicolae TAPUS*

Autor:

*Ing. Manuel Adelin Manolache*



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**UNIVERSITY POLITEHNICA OF BUCHAREST**  
**Faculty of Automatic Control and Computers**  
Computer Science and Engineering Department



**PHD THESIS**

**Integrated Decision Making Environment**

Scientific Adviser:

*Prof. dr. ing. Nicolae TAPUS*

Author:

*Eng. Manuel Adelin Manolache*



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# 1. Introduction

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The Webster dictionary defines decision-making as: “the act or process of deciding something especially with a group of people; a conclusion or resolution reached after consideration”.

Decision making is the key factor in human evolution, thus optimizing this process to a state of coherence with the organic, natural framework that life provides will most likely bring a huge enhancement in the quality of life for all participating members. [1]

In order to better understand the problems our predecessors had to face regarding decision making we looked into the main scope it was used for, which is social governance, and we identified the best formulated questions and statements that arose so far regarding it. By doing so we clearly defined the problem of governance and decision making in a very articulate way so that the solutions become obvious. [2]

As the complexity behind the social structures humans create increases so the mechanisms that allow us to coordinate with each other must evolve to cover our needs for each particular context where governance and decision making are required. Because the framework created by modern technology encourages human connectivity to become a basic need and requirement we can soon replace most of the archaic and outdated governance systems with global online platforms and protocols that are better suited to manage and optimize the way we act and evolve as a society and at the same time provide a transparent resource management system which will allow for the total eradication of corruption. [2]

Human decision making efficiency is dependent upon the governance system of the deciding agents and the roles they play. Aligning the context in which a decision impacting human life/society is made to a natural organic context, such as the one governing the cells of the human body and described by the anatomy of the body as a whole and biological algorithms that drive communication and decision making within the cell ecosystem, will increase efficiency and personal satisfaction and happiness, provided by the increase of individual expression supported by the self representation organic decision making platform in discussion. A system of this sort, capable of changing the context decisions are made into a more organic and natural one, can be achieved with the help of modern day technology and parts of it can already be found in some of the most popular social networks and online collaborative platforms on the web.

The platform we're proposing will play a key role in the upcoming paradigm shift from representative governance to self governance, the architecture, functionality and interface of the platform was modelled after the human anatomy and various other elements inspired by nature and natural phenomena.

The most used methods so far to query the human collective intelligence rely on polls and surveys. In all these classic methods the results are gathered from individuals in isolation, without them being able to coordinate with the group in real time and through some mechanism of dynamically interacting with the collective, reach the best potential of their solutions or ideas. We can't say that using methods such of these, where the participants lack connectivity with each other, we have access to a unified collective intelligence. The effectiveness of surveys and polls is thus limited to capture the average sentiment that characterizes a population but no collective intelligence can emerge from such methods.

Even in cases where there are methods for people to influence each other, like Reddit, this is done asynchronously. [3]

The issue with this type of asynchrony is the introduction of social biasing, also known as herding or snowballing effects. Some studies found that the first single up-vote can influence the final decision by up to 25%. This, in the case of prediction markets translates to momentum effects like price bubbles, risk-aversion biases and over-corrections.

In order to achieve true collective intelligence when having to do with a large number of individuals we can use the natural process of swarming found in biology. Because swarms rely on individuals working in parallel we see that social biasing effects are greatly limited and large groups can act and pursue a common goal as one unified organism. [14]

Although human evolution was primarily driven and inspired by observing nature and natural phenomena, little to no effort was allocated to finding ways in which we can integrate the solutions nature has to offer in the way we organize ourselves as a society and the way we make decisions as individuals or groups. Decision making, as a concrete manifestation of our will, is the fundamental process that allows for meaningful change to happen. Optimizing the way we make decisions and creating correlations between the decisions we make, the actions implied by those decisions and the effects the actions bring on the governed body (individual or group) will allow us to improve both the way we make decisions and the outcome of our decisions, while at the same time help us to identify the primary directives that need to be considered as fundamental parameters when making decisions that affect organic life, with the intention of



reaching a consensus, in the form of a universal wise normative that will be unanimously accepted by all humans regardless of gender, nationality, religion etc. [4]

Group decision-making is a situation where individuals collectively make a choice from a set of alternatives they are presented with or themselves identify. This type of decision isn't attributable to any single individual who is a member of the group. This is because all the individuals and social group processes such as social influence contribute to the outcome. The decisions made by groups are often different from those made by individuals. Group polarization is one clear example: groups tend to make decisions that are more extreme than those of its individual members, in the direction of the individual inclinations.

According to the idea of synergy, decisions made collectively tend to be more effective than decisions made by a single individual. However, there are also examples where the decisions made by a group are flawed, in these cases the decision power is spread equally among the deciding members but this can be solved using weighted votes based on trust.

Group decisions are affected by the same factors as social groups. Groups that have a high level of cohesion, combined with other pre-existing conditions like ideological homogeneity and insulation from opposing opinions influence the group decision making process in a negative way and reduces its effectiveness. Also, whenever an individual that's part of a group has to make a decision he exhibits a bias towards using and discussing mostly about shared information rather than unshared information, this is called shared information bias.

When experts that are part of a group have to solve a problem they think about it in very different ways, so their opinion regarding the decision that has to be made differs even though they are referring to the same situation. [5]

In order to allow different experts to work as a cohesive group we can use a Bayesian Network so that even though they might have different solutions they will be able to identify a causal relationship between the variables inside the Bayesian Network and quantify the graphical models with numerical probabilities. Even when facing a simple problem the approach of different experts as well as their knowledge can be very different. Without an objective and quantifiable way of comparing and sharing the different solutions and approaches it's virtually impossible for experts to come to an unanimous decision. [6] [7]

The solution for group decision making we propose in this paper combines mechanisms we see in nature, like swarm behavior and neuron decision making patterns, to create an organic hierarchy based on trust that offers the advantages of weighted votes while at the same time

guaranteeing every member of the group, regardless of their current status, the possibility of expressing their solution in a way that can be easily observed and considered by the group and eventually integrated in the final decision if it actually brings value. [8]

The framework and methodology we propose involves transforming the collective wisdom into a set of decision making statements that are dependent on identified probability constraints used for inference in a Bayesian Network.

For each of the identified probability constraints we will integrated the trust rating of each member that supports it so that members with a good track record, that demonstrated their value over time, will weight in more in the final decision than members that have no past contributions.

### **Defining the problem with Governance**

Before jumping into trying to solve a problem we must first have a clear understanding of what the problem is. For this we consider some relevant definitions given to the problem of governance over the years:

“Imperfect or lack of knowledge on how to collect and integrate distributed knowledge for the purpose of value creation” [9]

“Governance issues arise when knowledge relevant to production exists fragmented among different actors” [9]

“It is far from clear how highly distributed knowledge can be integrated and steered to a coherent collective output in the online environment” [10]

So to summarize the previous quotes: information relevant to governance and decision making is scattered among different entities without any way of centralizing it in a meaningful.

### **Relevant Quotes**

“the kingdom of God is within you and it is outside you.” Luke 17:21/ Gospel of Thomas

“If you bring forth what is within you, what you bring forth will save you. If you do not bring forth what is within you, what you do not bring forth will destroy you.” Gospel of Thomas

“Just as each of us has one body with many members, and not all members have the same function, so in Christ we who are many are one body, and each member belongs to one another. We have different gifts according to the grace given to us.” Romans 12

“No problem can be solved from the same level of consciousness that created it.” - Albert Einstein

“The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence.” - Nikola Tesla

“When wireless is perfectly applied the whole earth will be converted into a huge brain” - Nikola Tesla

### **Teleology**

Teleology ((from Greek telos, “end,” and logos, “reason”) is the philosophical position that describes things in terms of their apparent purpose, directive principle, or goal, so the universe and everything in it has a cause and a purpose. A teleological biology is one that thinks each organism has a certain "end/purpose" (Aristotle believed this).

Based on the teleological philosophy the purpose of each organism is the cause of their existence, based on this idea we can infer that the solution for the governance problem lies inside of all living organisms as an intrinsic property that could be observed through their anatomy, function, collective behavior or internal biological or genetic mechanisms. This conclusion seems to be confirmed by recent scientific discoveries studying ant colonies, honey bee swarms, and human neuron decision making mechanisms as well as represented in more abstract forms in the anatomy of the human body, which could be seen as the blueprint of a decision making platform architecture.

### **Organicism**

Organicism is a philosophical perspective that considers the universe and the parts it's made of as organic wholes and as living organisms.

The Organicism movement is still very relevant today and together with reductionism and mechanisms constitute important traditions when it comes to the history of natural philosophy, given that the ideas behind these concepts dominated science since the 17th century.

One of the most prominent representatives of this philosophy is Plato, which thought of the universe as a conscious and intelligent being.

Jean Baptiste Lamarck during the era of German romanticisms defined the science of biology and Organicism flourished during that time.

In modern times Organicisms is seen by the biological sciences as an approach that concentrates more on the organization, self organization in particular, of biological organisms rather than their composition.

The first time the term Organicism was used by a biologist to describe their philosophical views was in 1917 by John Scot Hardlane, and many others followed in the 20th century

Considering organicism together with the ideas behind teleology we can conclude that the intrinsic fractal property of self similarity can be observed as a pattern in many philosophical schools of thought and in modern times in can also be identified not only in social sciences but also in real sciences like computer science and mathematics. One of the objectives of this thesis is to make the first step into the correct direction in which human decision making and governance should evolve and identify, design and analyze some of the primitive components that would make up such a system.

## **1.1 Motivation**

Because we now possess the technology to recreate our body's perfect governing system it's only natural we implement it and start using it, and in doing so remove all possibility of corruption to ever take over the governing process like it happened so many times in the past.

By implementing a decision-making system that's specifically designed for us by nature itself, and use it in fields such as social governance, we take the responsibility from any small governing group of people and distribute it to each and every one of us, in accordance to our individual capabilities and predispositions.

Using an organically coherent system of governance emergent from the natural fractal expressed in the anatomy of the human body, such as the Integrated Decision Making Platform we are proposing, will align the human race to its full evolutionary potential, both at a personal and social level. In order to achieve this we need to gather, classify and act upon any good ideas that can arise in anyone's mind, not just a few that are in power at a certain time, like the previous, prone to corruption, systems. [2] [11]

**Purpose:** alignment with the current paradigm shift from representative governance to self-governance (freelancing, crowdfunding, Wikipedia, Reddit, bitcoin)

**Context:** the exploitation of people and natural resources in destructive ways by unwise leaders, the need for an organically developed global governance platform

**Applications:** provide a platform that facilitates self-representation in any form of social organization, collect and integrate distributed knowledge and tap into the collective wisdom with the purpose of solving common interest issues, accelerate the evolution of the human society by allowing an ecosystem of collaborative issue farming and solving to be formed, provide transparency managing resources, replace current key performance indicators, built around economic growth, with meaningful metrics that determine quality of life increase

### **Personal Motivation**

What led me to study the organic nature of decision making was the fact that I was born with Cystic Fibrosis, and as a Computer Scientist I had to study and understand the nature of this genetic anomaly from the information technology point of view. During college, in parallel with doing the computer science related work, I also researched the way the human body is built, how genetic code influences our health and mind, about the epigenome, how the nervous system works and how everything is centrally coordinated by the heart using the brain. During the research I discovered, among other things, that the human body and all organic entities use the MVC pattern(model, view, controller) to interact with its subcomponents and the outside world. The brain has a double function of interface(view) and switchboard(control) that uses the genome and epigenome data (model) to control the internal and external processes and behavior of the governed body. The architecture and algorithms used for the platform follow the design metaphor of many organic processes found in biological entities, swarm behavior, hive mind and is accurately depicting the human body anatomy.

The research I've done regarding the organic integrated decision making platform, modeled after the human anatomy, swarm intelligence and biological protocols, which is to be used in all areas where decision making is required, like replacing the current archaic governance systems and decision making protocols, is in concordance with the upcoming paradigm shift from representative governance to self governance.

After I had a model of the human body I could understand and work with, I started playing with the switches, so to speak, by identifying and managing the rational and emotional patterns I had acquired during my life and fine tuning them to mitigate the hypersensitive nature I was born with as a consequence of the genetic anomaly in Cystic Fibrosis.

From what we know about Cystic Fibrosis, combined with the research done on fractals and fractal properties, like self-similarity, I concluded that the hypersensitivity to internal and external stimuli(emotional and rational) I was experiencing was a fractal consequence, based

on the self similarity property, of the fact that CFTR(Cystic fibrosis transmembrane conductance regulator) gene handles and regulates the epithelial cell membrane permeability. What that means is that I had no consistent way of filtering and managing the inputs and outputs of my own body, both emotionally and mentally, and as a consequence I was manifesting pseudo-random effects that were influencing my health and creating all of the symptoms associated with CF. Once I got a good understanding of the mental and emotional processes and algorithms I unconsciously built and acquired during my life and focused on making them consistent and complementary with each other instead of conflicting, thus achieving a state of mental heterogeneity, all the Cystic Fibrosis symptoms slowly disappeared and all medical test results came out perfect. What I noticed that had the greatest impact on my health wasn't necessarily the input I was acquiring from the outside world but the output, the attitude that generated my reactions to external stimuli. So even if we can't control what we get from the outside world, we can control how we respond and react to what we are given and in that lies the power of epigenetics which allows us to rewire the pre-defined genetic responses to the environment and eventually achieve coherence as both individuals and as a society. The human body and all living things for that matter have a built-in perfect system of governance relevant to the society they can form. Based on these assumptions I started researching into how we can apply the structure, processes and algorithms that govern our bodies to the society we form in order to achieve a higher level of coherence and alignment with the natural way things are designed to be. And through research done in fractal theory we can better correlate the cause and effects for each human experience and fine tune the parameters based on which it was generated with the end goal of filtering out the bad experiences and improving the quality of life for all members belonging to the organism we call planet Earth.

## **1.2 Objectives**

In order to have a clear goal in mind we will define the objectives of this thesis .

The primary objectives are:

- design the architecture of the integrated decision making platform following the identify natural patterns involved in decision making
- create the blockchain structure and block types
- define the components of the decision making platform
- create a configuration protocol that works with the blockchain

- integrate the organic concepts related to decision making as observed in natural systems with the technological frameworks currently available

Secondary objectives:

- describe relevant patterns involved in decision making in nature
- create the user interface for the components of decision making platform
- integrate previous systems or research projects regarding decision making
- define the mathematical model for the decision making component
- identify and define ways to apply the decision making patterns and mechanisms found in nature in improving health
- bring in relevant knowledge from other domains relevant to decision making like medicine, psychology, quantum physics, religion

### 1.3 Chapters overview

In **Chapter 2** we analyze in terms of strengths and weaknesses different online platforms that contain the partial implementation of some important features that make up the Integrated Decision Making Environment.

In **Chapter 2.1** we discuss about the Unanimous AI, Unanimous AI is one of the most organic decision making platforms out there. It uses an intuitive swarm decision interface modeled on honeybee swarms. The authors of the platform describe it in a few articles[11].

The idea behind the Unanimous platform is based on the decision making process of honey bees. The honey bees form swarms that rely on decision making for optimum efficiency when it comes to gathering resources and protecting their hive.

There are three main functions of a swarm that we want to replicated in an online system:

- integrating noisy evidence, each individual brings their own information and many times this can contradict other participants in the decision making process, thus creating informational noise or uncertainty
- weighting competing alternatives, this should allow for different ideas to be objectively presented and compared, so that the conclusions being drawn from putting together multiple conflicting versions of information describing the same idea, solution or phenomenon to be coherent, meaningful, concise and clear

- converge to a single decision in a synchronized way, so that each participant will be able to perceive and change their reaction in real time, thus forming a feedback loop that encloses the full population of participants

Forming human groups by connecting users in real time systems that model the biological swarms can produce more accurate predictions than just following classical methods of tapping into the collective intelligence like polls, votes or surveys. This type of emergent intelligence observed in human swarms has been called Artificial Swarm Intelligence (ASI).

In 2015 a study was conducted that tested the ability of human swarms to predict the results of different college football games.

For this study a swarm was formed from the 75 participants that were all fans of the sport. The human swarm formed by them tried to predict 10 football game results. When acting alone each individual had a 50% chance of correctly predicting the outcome of an event but when acting together, as a swarm, the predicted results gone up to 70%. We can observe that an organic interface that allow humans to act as one swarm enables emergent enhanced properties specific to a super organism. The boost in performance is natural to any synergistic system where the whole is greater than the sum of its parts.

The main difference that separates a swarm from a crowd is that in a crowd the input is provided in isolation, such that there is no collaboration between individuals, thus the final solution is only the average of all individual solutions, which of course is inferior to the best solution that can be found in the group, but in the case of swarms the members can collaborate in real time thus acting, thinking and behaving like one body, converging on solutions in synchrony as real-time systems governed by intelligent algorithms. We can model the swarming process from biological systems like ant colonies, bee swarms or even neurons.

In **Chapter 2.2** we discuss about the Facebook social network. Facebook was one the most popular social networks at the moment when the research for the Integrated Decision Making Environment was being done. The reasons behind its popularity has to do with basic human psychology and built-in biological gratification mechanisms driven by self expression and social validation. Facebook offers both means for self expression and social validation.

The reason why Facebook is a very relevant platform for the integrated decision making environment is because it shows how successful social network platforms can integrate and innovate existing technology on the fly, while maintaining strong user growth.

In **Chapter 2.3** we discuss about Wikipedia.



The Wikipedia platform is supported and hosted by Wikimedia Foundation and it can be freely accessed by anyone on the internet. The people that can access the site will be able to edit articles following established protocols and website policies. Wikipedia is one of the top ten most visited websites on the internet and is the largest and most popular general reference work. Wikipedia is considered a “resounding success story” as a collaborative system where people can freely participate.

It is still to be determined whether if the success of Wikipedia resulted from the wisdom of the crowds or it was based on a small number of elite users that did most of the work. The data suggests that the success was achieved mainly because of a small number of committed and knowledgeable users and only recently there was a shift towards a greater participation of common users.

Because the users don’t have to pay any fee or even register to participate in adding or consuming content allowed for a solid foundation that assured rapid user growth.

One of the key strengths of Wikipedia lies in the contributions of new users that make few edits, which suggests a kind of wisdom of the crowds effect where more and more people are making small contributions to improve quality. Even so many prolific Wikipedia users argue that only a small number of users rather than the masses are the driving force behind Wikipedia’s success, so that more than half of the content was added or edited by only 2.5% of the users.

In **Chapter 2.4** we discuss about Reddit. Reddit is one of the best content aggregation social networks out there. One of the things we want to analyze when it comes to this platform is the algorithms that are used to highlight the relevant content submitted by users despite the high number of content that is submitted every day. The reasons the Reddit algorithms are so important to us is that they mimic the way the human central nervous system filters and prioritizes messages coming from the outside and within the body using ganglions. The human ganglions behave like the Reddit platform so that outside signals with a high degree of criticality gets sent to the brain while irrelevant outside stimuli gets ignored by the conscious mind and just pass to the autonomic nervous system.

In **Chapter 2.5** we present a few blockchain implementations relevant to decision making. Some of the most important ones are Bitcoin, Futarchy, Tezos, DFINITY.

In **Chapter 3** we will present the fundamental theories that constitutes the basis on which the Integrated Decision Making Environment was designed.

In **Chapter 3.1** we discuss about Swarm Intelligence for Decision making. Each year during spring the honeybee swarms need to make a collective decision of selecting the best place for a new colony. For this the oldest and most experienced scout bees search a large area and bring back alternatives to the swarm. They try to influence and convince the swarm about the location they found by using body vibrations, referred to as “waggle dance”. Using these body vibration the bees also send out information about the location of the new colony site, like distance or direction. Using this special dance honeybees can also transmit inhibiting signals to other bees. Using this method a closed loop feedback control is created that uses both excitation and inhibition, so just like neurons the honey bees create a closed-loop dynamic system of units working in parallel, where each bee supports other bees that prefer the same alternative and inhibit the ones that want different alternatives. When a sufficient quorum of highly excitable units is reached the decision is made. Using this method the honeybee swarm can select between dozens of alternative colony sites spread across 30 square miles, while evaluating each alternative based on multiple criteria.

Because the decision of selecting a new colony is not one based on isolated voted, but made through live negotiation of different alternatives as a group, the place they end up using usually is the one that best satisfies their requirements. By not using a voting system the result isn't the one that's most popular but the one that's best for the group. Real-life negotiation where many alternatives are considered and participants are interacting in synchrony to inhibit and excite others allows for the best solution to be chosen so that the group satisfaction is maximum.

When making decisions in a human context we can't rely on the quality or enthusiasm of someone dancing to trust them, but instead we can find the human equivalent of the bee dance that would allow us to trust that person.

The human mind is capable of understanding the passing of time and at the same time, using our memory, see someone's life as a static picture. This static picture we can create in our minds of someone's life can be considered their dance based on which others trust their judgment and the alternatives they are proposing.

In **Chapter 3.2** we present Bayesian statistics and Bayesian Networks and how they combine with Swarm Decision Making. Bayes' theorem allows us to create relationships between different conditional probabilities. By conditional probability we refer to how probable one event is based on other occurred events, the events that already occurred can be given a fixed value based. For instance, "what is the probability that the altcoin is profitable?" will have a

different answer than "what is the probability that the altcoin is profitable given that the creator is Vitalik Buterin?"

A Bayesian Network (BN), or belief network, is a probabilistic graph model(GM). Using a BN we can represent knowledge with a certain degree of uncertainty about different domains, each node in the graph is a variable while the edges of the graph represent the probabilistic relationship between the two variables. [12]

In order to estimate the conditional dependencies between the nodes of the graph we use known statistical computational methods. A BN combines different principles from probability theory, statistics, graph theory and computer science. The BN is represented using a structure called directed acyclic graph(DAG) which is very popular in statistics, artificial intelligence and machine learning. BN are mathematically rigorous and also intuitive so using them we can achieve an effective computation and representation of joint probability distribution (JPD) for a set of random variables. The DAG can be defined by two sets, the vertices or nodes and the set of directed edges. The nodes are drawn as circles and represent a random variable, they are labeled with the variable name. An edge represents a direct dependency between the variables and are drawn as arrows between nodes.

In **Chapter 3.3** we present the anatomical components of the human body and how the way they function is important for a decision making system. The Integrated Decision Making Environment is modelled after the anatomy of the human body. The most relevant biologic system in the human anatomy to decision-making is the nervous system.

The nervous system connects the brain, with its two hemispheres, to the rest of the body through the vertebral column and nervous ganglions located around the body. Ganglions, depending on their role, route and filter messages coming from individual cells.

A nervous ganglion is a nerve cell cluster or group of nerve cell bodies that has the purpose of intercepting signals coming from the neural cells located around the body, which have the role to sense external stimuli, and after filtering and prioritizing the signals, forwards them to the brain which decides on the action which will be taken according to the received signal.

The human nervous system is already built like the perfect decision-making system and all it's functions can be easily modeled and implemented into a real platform that humans can use to govern themselves as one heterogeneous body regardless of the number of people involved or their individual peculiarities.

The different organs and systems that the human body contains can be found in real life as Departments, Organizations, Corporations, etc, but without a central point of governance these organs act against each other instead of cooperating.

To understand the mechanisms used by the brain when making decisions we don't necessarily need a microscope, as we know from fractal theory, the general consensus is that theoretical fractals are infinitely self-similar and this also applies to natural fractals. The branches of a tree are distributed similarly to the Bronchial Tree that forms our lungs. The fractal form of our lungs isn't similar to the branches of a tree just by coincidence, both play a role in respiration, just how we use our lungs to breath, so are the trees the lungs of the Earth and used for the same purpose. [13]

The platform we're building is inspired by the biological governance model of the human body. We create a game model that uses a player(actor) or cell or neuron, a network for information distribution, the internet, and a processing unit that takes care of all possible player to player and player to network interactions using blockchain technology so that we form organic swarms similar to human nervous ganglions.

The human central nervous system is the unfolding of a fractal which sole purpose is to coordinate the activity of the human body and connect more than 38 trillion cells into one coherent organism. Because of its fractal nature, the central nervous system manifests self similarity, and because we have an idea about how the macroscopic mechanisms that make up the central nervous system work, we can infer that at a microscopic level the general functions are preserved but expressed in different forms. The division of the brain in two hemispheres united by the corpus callosum can also be found in a different form in the nervous ganglion.

Also the functional division of the central nervous system in autonomic (sympathetic and parasympathetic) and somatic is also proof of the underlying motif used by nature to divide and conquer.

The functions and structure of the central nervous system encodes the best interface and functionality that implemented into an actual platform, using modern technology, would enhance and mitigate the act of decision making for any group of individuals regardless of the issues being decided upon.

The human brain is split into 2 hemispheres and united at the centre through the corpus callosum that connects the spinal nerve that is the main agent that allows our limbs and organs to be coordinated with each other for the good of the body as a single coherent unit. From this we

can determine that there are 3 main roles that assures the good functionality of the body, the left hemisphere, the corpus callosum, and the right hemisphere. Medical research has shown that the right and left brain hemisphere have different, complementary roles when it comes to functionality. And the corpus callosum has the role of uniting and mediating between the two hemispheres and the rest of the body.

Creating the right environment and interface for the people that completely lack trustworthiness to be in charge of legislature would be ideal because the laws that they create provide the means for people like themselves to cohabitate without conflict. Thus, the same people for which the laws are needed, are the best people to actually conceive the laws. So the platform will act as a mediator for people that are focused only on their own self interest to protect themselves from people of the same nature.

In **Chapter 3.4** we discuss about fractals and how their properties, like self similarity, can allow us to identify relevant patterns in nature important to decision making. A fractal is a never-ending pattern. Fractals are infinitely complex patterns that are self-similar across different scales. They are created by repeating a simple process over and over in an ongoing feedback loop. Driven by recursion, fractals are images of dynamic systems – the pictures of Chaos. Geometrically, they exist in between our familiar dimensions. Fractal patterns are extremely familiar, since nature is full of fractals. For instance: trees, rivers, coastlines, mountains, clouds, seashells, hurricanes, etc. Abstract fractals – such as the Mandelbrot Set – can be generated by a computer calculating a simple equation over and over.

Natural fractals include branching patterns like trees, river networks, lightning bolts, blood vessels, etc., and spiral patterns like seashells, hurricanes, and galaxies. A tree grows by repetitive branching.

The body of being(nature/God) speaks in fractals, infinite complexity and meaning expressed in simple forms/formulas.

Using the property of self similarity specific to fractals, we can identify decision making patterns used by nature and apply them to the integrated decision making environment.

In **Chapter 3.5** we present Blockchain technology and why it stands out over all other data storage technologies. When we refer to a blockchain, at the broadest level, we usually refer to a network of databases that's spread across multiple entities and are synchronized, where there's no single controller or owner of the data. The databases tend to be append-only, that means they can be written to, however historical data can not be altered without a general agreement from

the participants of the network. This implies that a system administrator or user in one entity can not alter data contained on a blockchain without an existing general agreement from the rest of the participants.

Historically, in situations where various parties needed to trust the same data, we've used golden sources of data, controlled and held by third parties that can be trusted. A classic example could be the use of a clearing house as a golden source of data about transactions between two entities. The Blockchain has the option to empower groups of parties to agree on events without the need of a third party, this is one of the key features of this new technology.

In order to be part of a blockchain a user needs to install special software that connects them to other participants on the network. When you run the software you become a node in the network and you act like an individual validator. Once connected to the network for the first time a node will download the entire copy of the blockchain database on their computer.

The database is going to be managed by the nodes that connected as per the existing protocol. Each node becomes an entry point that can add new data to the network as well as validate and propagate other new data.

Even though, so far, most of the use cases for blockchain involved crypto currencies we can extend the way we use it in fields where it can have an even greater impact, like decision making and social governance. The distributed and decentralized database that the blockchain provides has 2 properties that makes it a perfect candidate to be at the base of a trust-less collaborative decision making environment:

- 1) Transparency - because data is shared between all the nodes of the network, which in the case of a decision making environment would translate to deciding agents, everyone will have access to the whole history of transactions or decisions that were taken until any given point, this means that any new decisions or transactions will automatically take into account previous decisions.

- 2) Incorruptibility - data stored on the blockchain cannot be altered because locally altering any unit of information on any given block would create an inconsistency between the altered blockchain and all other nodes on the network.

These two properties are crucial for creating a trustless decision making environment where each agent in the decision making process doesn't need to rely on the trustworthiness or good faith of the other agents. Because all information relevant to the decision making process is distributed between all deciding parties and all previous decisions can't be corrupted or

overturned by any of the participating member, each new decision that's being taken will be based only on real and relevant information. This will ensure that for every new decision making iteration the issue being decided on will be better understood and addressed.

In **Chapter 4** we will present the components and architecture of the Integrated Decision Making Environment.

In **Chapter 4.1** we present the Decision Making Environment components and blockchain configurations derived from the anatomical entities that form the human body and the structure and functionality of the central nervous system .

In **Chapter 4.2** we present a Holistic Model for Decision Making. The classical model of decision making is based on the assumptions that the deciding agents have access to complete information and are capable of making the optimum decision by weighting every alternative. Needless to say that this is never the case because such a capability can never be provided by systems that don't have a holistic view over the object upon which the decisions are applied and such unknown variables will hinder performance, profit or overall satisfaction.

The Integrated Decision Making Environment provides the means by which we can migrate from the classical 'blind' decision making model to a holistic model for decision making and management.

In Holistic decision making we are encouraged to be aware of our actions and impact they have on the whole. It creates an environment in which people take responsibility and accept being held accountable for their decisions. This empowers the deciding agents to be part of an ongoing process of change. Using a holistic approach allows for a number of different factors to be taken into account.

The Integrated Decision Making Environment, based on it's holistic approach, enables participants to make decisions based on their deeper values, which will be economically, socially and environmentally sound.

Holistic Management instead of seeing different parts as being separate will address all the parts as an integrated whole. Holistic management creates a new framework for decision making that is based on resource management of the whole on all its levels.

Using the Holistic Management methods, we can identify all the people that are important and the resources related to the issue that's being solved and bring them together as one whole with the help of a statement of purpose. With the broad holistic goal defined by the statement of

purpose, the group that is formed has a benchmark using which they can quantify the quality and efficiency of their decisions. A subsequent feedback phase reaches back to often ignored considerations to make sure that none are being forgotten, for this we will use the Feedback Component, based on the felicific calculus formula, that assesses the overall satisfaction for any given decision that was taken and begins another iteration of the decision process if needed.

In **Chapter 4.3** we talk about how we can use Blockchain technology for Decision Making and how we envision the Decision Blockchain.

Blockchain technology was first used in crypto-currency systems to keep a ledger for transaction. Each transaction was saved in a list and when the list arrived at a certain size a new list was created and the old list would be hashed, and the hash code to the old list would become the starting value of the new list so each block(list) would be chained and validate each other. This way if a change would have been done to an older list, let's say something would add a fake transaction so it would seem their account has more resources than it actually has, the hash of the resulting list would be different than the next list after it. So if you would actually want to add a transaction you would have to go through all old lists that were already processed and calculate a new hash for each of them. And that would be from a processing point of view almost impossible because the blockchain is distributed and the one doing the change would need more processing power than all the other nodes that keep a copy of the list put together.

A system of this sort should be used in the way we keep track of each decision we do as individuals and as a society. This way we will keep a track record of all decisions made that would be impossible to counterfeit from which we could extract and learn using Artificial Intelligence software the best course of action for each issue in such a way that new decisions would have the support of the best suggestions extracted from past data.

This can be applied to each individual but also to the governance structures we use in society in any form of organization, like education, transport, health, environment, economy, etc.

The blockchain is a way of storing data that creates a distributed and decentralized database which ensures data consistency through cryptography. Blockchain technology became popular because of the Bitcoin crypto currency. Crypto currency is a form of digital currency that uses the blockchain as a ledger for financial transactions, which also provides transparency because of its distributed and decentralized nature, and cryptography as a means of protection against double spending.



The governed body is made of the individuals that are affected by the decisions being made using the Integrated Decision Making Environment that's using the Decision Blockchain, which consists of Deciding Agents and Unqualified Users. Deciding Agents are individuals that have the right to submit decisions or vote on them according to the existing legislation stored on the blockchain.

Unqualified Users are either individuals that don't yet meet all the requirements to become Deciding Agents (because they are too young) or people that lost the privilege temporarily or permanently based on past behavior. Even though you are an Unqualified User you can still contribute to public debates and receive public acknowledgement through other types of votes, like vote of wisdom, and doing so indirectly influence the decisions being made.

The body of governance consists of Deciding Agents that are implicated in the decision making process and have specific roles that serve the governed body, or it's organizations and institutions, in the legislative, judicial or executive branch.

The Decision Blockchain can be seen as the artificially created DNA of any Body of Governance, where each individual is the equivalent of a cell and each cell contains a full copy of the whole blockchain just like biological cells contain a full copy of the DNA. Each fork created in the decision blockchain with the purpose of defining a new institution with its own internal rules and role is equivalent to the different organs of the human body that have specialized functions useful for the whole body, thus creating a virtual delimitation between the new institution (organ) and the rest of the body. The Deciding Agents have roles that are equivalent to the different cell types the human body, each with their own well defined purpose depending in what Institutions or Organizations they activate.

The similarity between the DNA and the Blockchain has important implications in the way we can debug the decision making process similar to how geneticists use DNA sequencing to trace back certain traits, properties or behaviors in different organisms to their genetic triggers. This can be done by using the structured data found in the blockchain which can be defined at a very low level of granularity and linking it to the observed effects it has on the governed body, which with the help of the feedback component are also going to be stored in the blockchain. Having created a strong link between causes and effects the deciding agents will be able to fine tune the decision making process and laws that govern the body so that with each iteration the body achieves a greater level of coherence and heterogeneity. It is known that biological organisms

evolve as a response to external factors and this property will also emerge and manifest itself inside any collective using the integrated decision making environment.

The biggest benefit of blockchain technology is that it can act as a decentralized system and cut out the middlemen. Smart contracts can be used so that automated pre-defined transactions will be triggered whenever certain conditions are met. Smart contracts are stored on the blockchain and all parties can access them using the decentralized system. If anyone tries to alter a smart contract the attempt will be rejected and the stakeholders will be informed. Smart contracts can function like automated lawyers once the infrastructure is in place. Using smart contracts we can immediately receive the documentation generated by the blockchain nodes instead of hiring a lawyer to authenticate and prepare the documentation. [14]

A very popular use of smart contracts is logistics and supply chain management. When a company is involved in manufacturing, shipping and selling their products the supply chain can become very complex and complicated to manage. Using a blockchain system would allow for the data to be standardised so that human intervention will be reduced. A blockchain properly set up to use smart contracts can cover the acquisition of raw materials, tracking of products from the time they are made to the time they are packaged and shipped and many other things so it can replace a lot of other systems that would be needed. (Fig 38). Using the blockchain with smart contracts will allow for fast bottleneck detection and tracking of lost products. When the departments of a company can easily collaborate and optimize the flow of products (Fig 41), complex information and financial transactions between them, excellence in logistics can be achieved. [15]

In **Chapter 4.4** we present the advantages of using MultiChain technology and how using it we can create the perfect Resource Management and Logistics component for the Integrated Decision Making Environment.

In **Chapter 5** we go into detail about each of the components that form the Decision Making Environment in terms of design and functionality, as well as possible blockchain configurations for each.

In **Chapter 5.1** we present the Trust Rank Component. In order to facilitate the identification of valid candidates and the creation of organic hierarchies based on the traits relevant to the process of governance or decision making we propose a dual voting system.

The first aspect that will be measured is the trust level of each individual and the second is the audacity and relevance of his arguments, also known as wisdom. For this we provide a

direct vote of trust to any individual you consider trustworthy in the case yourself don't want to be implicated in the governance or decision making process. The vote of trust will be singular, that means you can only give it to one person, and it can be taken back after a period of time, for instance 3 months, so we don't create changes that are too frequent in the organically created hierarchy and also make the person more responsible for their vote.

The people at the top of the trust hierarchy will be viable candidates for the executive branch of government or the agents that act out the implementation of the law and manage the institutions created for monitoring the correct implementation of the law.

For the Legislative branch we will create a hierarchy based on a peer validated voting system - when you up-vote/down-vote any issue or idea you also have to provide a reason for the vote, if the reason for the vote can't be defended against public scrutiny the vote will be invalidated. Users can argue against a vote and if the arguments are compelling and convince others that the vote argument isn't valid it will be invalidated. So if an argument against a vote that was given for whatever reason gets more up-votes than the vote itself, after a period of time depending on how many users voted on it and the ratio between up-votes and down-votes the vote will become invalid.

With this kind of voting system we can keep the advantages of weighted vote and at the same time keep democratic universal voting. You can vote but it doesn't mean your vote will actually count if the reasons behind it aren't relevant. One of the main reasons for voting is to achieve clarity regarding a certain problem by querying the collective wisdom, whatever we can do to filter out unwise or irrational people will bring more value and credibility to the result of the vote.

Quantifying the power of a voter relative to the clarity and rationality of his arguments is a good way to refine the voting pool and create a hierarchy based on objective values.

The algorithms used for sorting by confidence and popularity using the votes of trust are derived from the Wilson confidence score (score interval) and Reddit popularity sorting. Edwin Bidwell Wilson (April 25, 1879 – December 28, 1964) was an American mathematician and polymath. In 1927 he introduced the Wilson score interval, a binomial proportion confidence interval, and also derived the "plus four rule", which uses a pseudo count of two (add two to both your count of successes and failures, so four total) for estimating the probability of a Bernoulli variable with a confidence interval of two standard deviations in each direction (approximately 95% coverage).

Based on the organisms principle as well as the self similarity property of fractals we uses the human nervous system as an inspiration to create the Trust Rank Component.

In **Chapter 5.2** we present the Legislation Creation Component. The current way of creating new laws and regulations is very inefficient because most of the time it doesn't allow for the majority of those impacted by the laws being created to take part of the creation process in the form of suggestion and for those that actually are part of the creation process cooperation is very difficult because there is no way for all of them to equally intervene in the process. In order to address this issue we propose a collaborative legislature creating interface in which each law is split into smaller units called law atoms, which can vary in length from one sentence to one paragraph. Each of these law atoms will be saved inside a Decision Block so they can be changed independently from one another.

A law article will include many of these law atoms which can be voted upon individually and edit suggestions can be added to each atom and the suggestion list will show up as alternatives when you select a certain law atom. People will be able to vote on these suggestions and if a suggestion gets a certain number of votes the atom will be replaced with that suggestion.

This way all people involved in the lawmaking process will have equal power of influence over the law being created and only the best ideas will actually make it in the law.

After a law draft is finished it can be peer reviewed by the people that the law will affect and issues and suggestions can be raised that will reach the people in charge of actually creating the law. When the law receives enough public support it will become ready for publication and at a certain date determined in the creation process it will become active.

Each law atom will be saved in the blockchain as a decision so that anyone at any time can check the creation history of any given law and at the same time assure it's safe keeping.

The Legislation Creation Component will be based on way the human brain learns and makes sense of the world, using neural connections, circuits and networks. A neural circuit is a population of neurons interconnected by synapses to carry out a specific function when activated. Neural circuits interconnect to one another to form large scale brain networks.

In **Chapter 5.3** we discuss about the Feed Component, which has two main categories, News and Organic Developments. In the News category users can submit information which is relevant to the whole society, like inventions, theories, studies, scientific articles, major social events, and so on. [4]

The News category acts like a parasympathetic ganglion, without having any reaction attached to it, only monitors and broadcasts information for the whole human society to see.

Any individual can post in the News feed because the voting system will place the news at its right place as soon as other members categorize it as relevant or irrelevant.

The News feed can also be used to point to resolutions for other ongoing issues that Groups and Organizations try to solve or create policies for. If a Policy needs to be created to handle traffic in crowded areas but there is an Article in the News section that talks about Artificial Intelligence Traffic Management, the Group that is trying to develop a solution can reference that News article and bring the people involved with that discovery into the policy creation process and later on create a public Project for the solution to be implemented using that technology.

Organic developments allow everyday personal issues to be submitted so the community can collaborate into finding solutions. Organic development threads can consist of any type of issue someone can meet in his daily life, from relationship problems, infrastructure development, public transport issues, and even emergencies of any type like fires, car crashes, and so on.

In the Organic developments sections articles are going to be down-voted or up-voted depending on the relevance and also on the area of impact each issue has. If on residential area there is an urgent need for extra parking spaces someone can Submit a thread regarding it and invite all people living in that area to up-vote it. If the number of votes in a specified period of time reaches a certain threshold the criticality of the issue is increased and a message will be sent to Organizations and Parties that work in that specific area. Hashtags are going to be used to signal the area of expertise and other such properties for each Organic Development.

In **Chapter 5.4** we discuss about the Issue Framing Component. Issue framing is a vital part of the decision making process because it describes the problem we are trying to solve and a problem well-stated is a problem half-solved. In order to achieve the greatest efficiency in solving problems that are raised by the organization being governed we must separate the process of collecting issues into sub processes that work together to filter and prioritize the collected problems.

The first layer of filtering should be done organically by the masses using the trust rank voting system, the more people with high trust rating vote for an issue the more exposure it gets. [4] If a raised issue gains enough traction and popularity it will trigger the second layer of filtering in the issue framing process. The second layer of filtering should be done by the people with

the highest trust rank that were directly involved with the issue by voting or indirectly connected to the issue through people that voted on it. So if I have a high trust rank and up-voted for an issue or a person that gave me their vote of trust voted for an issue, I will automatically be involved in solving it as being the person with the highest trust rank in that context.

People with the highest trust rank can then decide to escalate the problem by framing it as a public issue so the higher levels of governance will become responsible to solve it, or they can address the issue themselves, together with the structures of governance they are in direct contact with.

The Issues section can be seen as a bug reporting application like Jira and Bugzilla but instead of reporting software bugs we report real life issues that are derived from the Organic Development Feed that reached a certain level of popularity and have groups of specialized citizens, parties or financial organizations find fixes for them.

In **Chapter 5.5** we discuss about the two main decision making interfaces, the Bayesian Decision Making and the Swarm Decision Making Component. When experts that are part of a group have to solve a problem they think about it in very different ways, so their opinion regarding the decision that has to be made differs even though they are referring to the same situation. [5]

In order to allow different experts to work as a cohesive group we can use a Bayesian Network so that even though they might have different solutions they will be able to identify a causal relationship between the variables inside the Bayesian Network and quantify the graphical models with numerical probabilities. Even when facing a simple problem the approach of different experts as well as their knowledge can be very different. Without an objective and quantifiable way of comparing and sharing the different solutions and approaches it's virtually impossible for experts to come to an unanimous decision. [6] [7]

The framework and methodology we propose involves transforming the collective wisdom into a set of decision making statements that are dependent on identified probability constraints used for inference in a Bayesian Network. [5]

Using the Bayesian Network decision making interface users are allowed to add belief factors that they consider most influential in determining the success probability of a given decision. In the case of ordering a pizza(Fig.8) the user has the possibility of adding all ingredients as well as their probability to generate a favorable outcome. By combining the belief factors of members we can obtain an accurate representation of the collective preference regarding the

ingredients that should go on a pizza for it to be considered delicious. The Bayesian Network interface for decision making is preferred to be used in cases where we have to deal with quantifiable parameters.

The Swarm Decision Making interface is better suited for decisions that depend on subjective beliefs or feelings that can't be easily quantified. Also the decision making process in the case of the Swarm Decision Making interface is faster and happens in real time. The real time negotiation being done through an intuitive interface and not numerically as in the case of the Bayesian Network.

In **Chapter 5.6** we discuss about the Feedback Component. One of the most important components of a decision making environment is the feedback component. The feedback component is suppose to measure the success of the decisions being taken using the platform and provide an objective scale that we can use to compare different decisions and how they impact the governed population.

The algorithm used for such a component can be inspired by the “Felicific calculus algorithm”, which was formulated by utilitarian philosopher Jeremy Bentham (1748–1832) for calculating the degree or amount of pleasure that a specific action is likely to cause.

Bentham, an ethical hedonist, believed the moral rightness or wrongness of an action to be a function of the amount of pleasure or pain that it produced. The felicific calculus could, in principle at least, determine the moral status of any considered act.

Included in this calculation are several variables (or vectors), which Bentham called "circumstances".

Because a complex evaluation is not always required or some users might prefer to give a simple feedback we will have two Feedback Types: Simple Feedback and Extended Feedback.

The Simple Feedback will provide a very intuitive interface consisting of a slider with a smiley face that progresses from sad to happy depending where it is positioned. For simple feedback we will insert values for each parameter of the felicific calculus algorithm relative to the position of the slider, starting at -1 for completely unsatisfied going up to +1 for completely satisfied.

The Feedback Component will be used to gather feedback from the governed body, measure the success of the decisions being made using the platform and provide an objective scale that can be used to quantify the success of different decisions, how they impact the satisfaction of

the governed population and how they affect the performance related to reaching the goals derived from the purpose of the group using it.

The factors relevant for configuring the Feedback Component are:

- System complexity: if the integrated decision making environment will be used by a large organization with a complex internal structure then it's vital to receive complex feedback from all members to fine-tune the decision making process.
- Products and services being delivered by the organization using the platform: in cases where the products or services being delivered by the organization can be improved if internal feedback is gathered.
- Importance of member satisfaction: if the members that constitute the governed body are also the beneficiaries of the products and services the organization provides, the feedback component needs to be enabled.
- The decision making process inside the organization depends on accurate internal information: when the performance of the organization depends on how accurate the internal information is the usage of the feedback component will highly increase the performance of the operations and quality of products delivered by the organization

The Feedback Component was inspired by the biological principle of homeostasis and feedback loops. Without feedback, homeostasis cannot occur. This means that an organism loses the ability to self-regulate its body. Negative feedback mechanisms are more common in homeostasis, but positive feedback loops are also important.

In biology Homeostasis is the tendency of an organism or cell to regulate its internal environment and maintain equilibrium, usually by a system of feedback controls, so as to stabilize health and functioning. A body is in homeostasis when everything is functioning properly and its needs are met.

The organs of a body all contribute to hemostasis, a complex set of chemical, thermal, and neural factors interact in complex ways, both helping and hindering the body while it works to maintain homeostasis.

In **Chapter 5.7** we describe how components work together to form a coherent and unified decision making environment. Just like the components of a car, each component of the Integrated Decision Making Environment can very well work independently and provide a



specific function relevant to the decision making process, but when they work together the synergy becomes obvious. Just like a car provides additional functionality that can't be found when the components are used independently, so does the Integrated Decision Making Environment starts to feel like a real organism that automatically regulates itself to better cope with the external and internal environment with the help of the deciding agents that act within the roles they are given by the organism they live in.

In **Chapter 6** we present a few use cases for the Integrated Decision Making Environment can be used.

In **Chapter 7** we present the Conclusions of our research and how the Integrated Decision Making Environment can be used in the future.

## 2. State of the Art

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The following chapter will provide a short description of existing platforms and systems that have already implemented some of the features contained by the integrated decision making environment.

For each of the described platform and system we will discuss the strengths and weaknesses in order to have a clear idea of what we want to achieve with the integrated decision making environment without repeating any existing mistakes and making sure we extract all the wisdom put into the existing systems.

### 2.1 Unanimous AI

Unanimous AI is one of the most organic decision making platforms out there. It uses an intuitive swarm decision interface modeled on honeybee swarms. The authors of the platform describe it in a few articles:

The idea behind the Unanimous platform is based on the decision making process of honey bees. The honey bees form swarms that rely on decision making for optimum efficiency when it comes to gathering resources and protecting their hive.

There are three main functions of a swarm that we want to replicated in an online system:

- integrating noisy evidence, each individual brings their own information and many times this can contradict other participants in the decision making process, thus creating mental noise or uncertainty
- weighting competing alternatives, this should allow for different ideas to be objectively presented and compared, so that the conclusions being drawn from putting together multiple conflicting versions of information describing the same idea, solution or phenomenon to be coherent, meaningful, concise and clear
- converge to a single decision in a synchronized way, so that each participant will be able to perceive and change their reaction in real time, thus forming a feedback loop that encloses the full population of participants

Forming human groups by connecting users in real time systems that model the biological swarms can produce more accurate predictions than just following classical methods of tapping

into the collective intelligence like polls, votes or surveys. This type of emergent intelligence observed in human swarms has been called Artificial Swarm Intelligence (ASI).

In 2015 a study was conducted that tested the ability of human swarms to predict the results of different college football games.

For this study a swarm was formed from the 75 participants that were all fans of the sport. The human swarm formed by them tried to predict 10 football game results. When acting alone each individual had a 50% chance of correctly predicting the outcome of an event but when acting together, as a swarm, the predicted results went up to 70%. We can observe that an organic interface that allow humans to act as one swarm enables emergent enhanced properties specific to a super organism. The boost in performance is natural to any synergistic system where the whole is greater than the sum of its parts.

Another similar experiment was conducted on another group that was required to predict English Premier League soccer matches, in this experiment it was shown a 31% increase in the accuracy of the predictions compared to the case where the participants would predict the games in isolation.

There have been previous similar experiments where artificial swarms showed an amplified rate of prediction of human groups when it comes to predicting sport events, presidential elections, or Oscar awards but no formal study has been done to assess if a human swarm would show increased efficiency in predicting financial markets. In order to test this a study was conducted where human swarms of financial traders were asked over a fourteen week period to make predictions on four financial indices. The purpose of this study was to assess whether there is a significant improvement of the human swarm over individual predictions. The human swarm was also compared to classic methods of gathering information from groups of people like surveys, polls, etc. So this study presented the predictive efficiency of three different classes of human associations,; crowds, swarms and individuals.

The main difference that separates a swarm from a crowd is that in a crowd the input is provided in isolation, such that there is no collaboration between individuals, thus the final solution is only the average of all individual solutions, which of course is inferior to the best solution that can be found in the group, but in the case of swarms the members can collaborate in real time thus acting, thinking and behaving like one body, converging on solutions in synchrony as real-time systems governed by intelligent algorithms. We can model the swarming process from biological systems like ant colonies, bee swarms or even neurons.

The Unanimous A.I platform that implements Swarm AI technology was mainly modeled after honeybee swarms. The honeybee swarm was chosen because of its increased accuracy when it comes to critical decisions by allowing participants to create real-time systems, similar to a hive mind, that can act as a single organism of amplified and unified intelligence to solve problems. The first time the decision making process of honey bees was studied was in the 1950s, and it was discovered that it's very similar to the brain neurons decision making process. In both cases we have a large population of simple units that can get excited (bees vs neurons), which work in parallel to integrate individual uncertain knowledge, compare different alternatives and decide unanimously on only one solution.

In both the case of honey bees and neurons we have a real time competition between subpopulations of excitable units. The swarm reaches consensus and converges to a single alternative when a subpopulation reaches a certain threshold level of support. This allows the group to find the optimal solution more than 80% of the time.

The fact that honey bee swarms and brains are very similar becomes obvious when we compare the decision making process model of each. The decision process model in primate brains is described as being mutually inhibitory leaky integrators that aggregate evidence from competing neural populations. The Usher-McClelland model of primate decision making can be seen below (Fig 1).

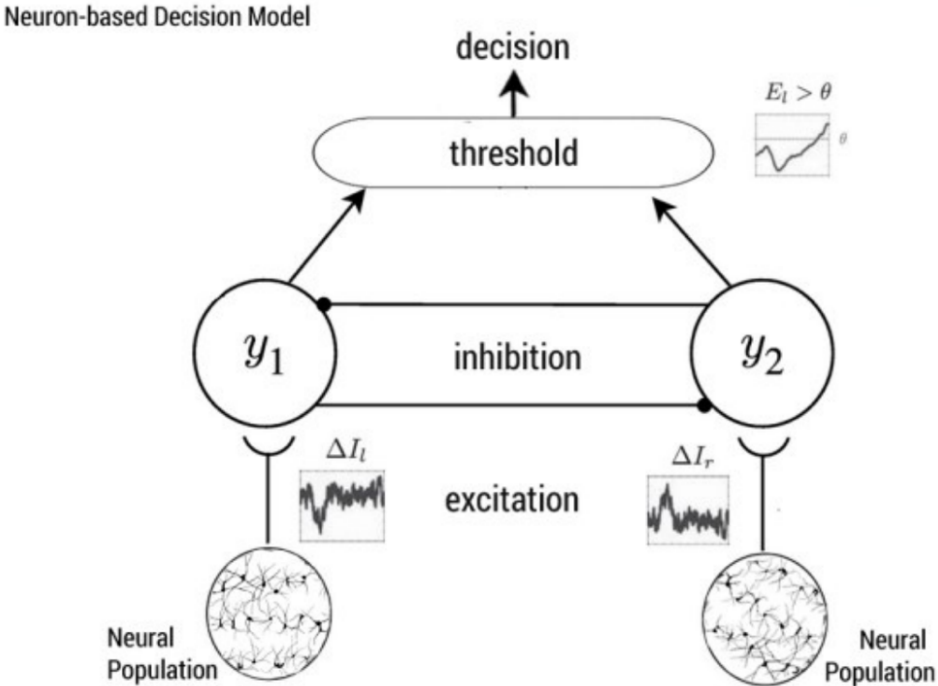


Fig 1. Usher-McClelland model of neurological decision-making

The Usher-McClelland model can just as well be applied to the swarm-based decision model, with the only difference of honey bees being neurons. In both cases the process of decision making aggregates input from swarm members, that form subpopulations, by mutual excitation and inhibition until the threshold is reached. We can thus assume that this model provides a good representation of how intelligence emerges, swarms being systems of brains organized in such a way that amplified intelligence is achieved.

Unlike other species humans have no natural way of forming closed loop systems that would allow for real time swarming to occur. Species that can form swarms use high speed feedback loops among the members, but humans don't have organic equipment for that to happen. Fish create schools by detecting vibrations in the water, birds flock together by detecting subtle motions that propagate through the populations, bees create swarms by using body movements called a "waggle dance".

In order for humans to create artificial swarms we can rely on technology to create special user interfaces, algorithms and protocols in that would allow us to close the loop among all members. For this purpose a technology called Swarm AI was created which enables groups of human to be connected to each other in real time forming artificial swarms. The first online platform that used this technology is called UNU. The platform allows distributed groups of people to form closed-loop artificial swarms using a regular web browser. The UNU interface consists of a magnet that allows the users to move a puck in the direction of different alternative answers. This way all users act on the puck in real time and can interact with it, trying to get it to the position where the alternative they prefer is. By having the puck as a center piece that all users can interact with the group now exhibits properties similar to a honey bee swarm. Each user interaction is a stream of vectors instead of a discrete vote like in regular information gathering systems. The artificial swarm moves in real time based on the full system dynamics not on the input of any single individual. Users can adjust their intent continuously and adapt to the state of the system at any given time until a solution is collectively selected. This promotes an ongoing and complex negotiation between all members, allowing the group to explore different alternatives and converge to one solution in synchrony.

Because the puck is always moving across the decision space, members have to continually move their magnets and keep them close to the puck in order to influence it. Participants don't only change the direction of the puck based on their intention but also the force at which they influence the puck depending on the distance from the puck. This is important because during this process participants can reevaluate their intent as they interact with other participants

through the motion of the puck. The further from the puck they position their magnets the less power to influence the final decision they have.

This mechanics emulates very closely the honey bee vibrations through which they excite or inhibit each other. In the same way the neurons that make up a biological neural network fire activation or inhibiting signals to express their level of conviction. Each member has to continuously update and express their preference based on the possibilities the swarm gravitates around during the decision making process. [7]

**Strengths**

Unanimous AI offers a very good proof of concept when it comes to showing the benefits of human swarming. Because it offers a very intuitive GUI similar to a honeybee swarm, each person has power to influence the end result at all times until the final decision is made. And even if your preferred option isn't going to be picked you still have to ability to influence what the final result will be.

From this platform we can integrate their GUI(Fig 2). for voting on simple issues, as well as understanding in a human perspective how decisions are being made inside a bee swarm.



Fig 2. Unanimous GUI that creates a human swarm

## **Weaknesses**

The main problem with the Unanimous AI decision making system is the fact that it only allows for simple decision to be made, decisions that don't require the sharing of information between deciding agents, and at the same time it abstracts personal away decision factors, thus only allowing for a subjective final opinion to be observed and considered by the group making the decision.

Another aspect that is lacking is the fact that each member of the swarm has equal 'power' in influencing the final decision that is being made, and because of that people that are more knowledgeable about certain issues that are being voted on will not be able to steer the group to the best solution, as their voting power equals that of the average ignorant member that takes part in the decision making process.

## **2.2 Facebook**

Facebook was one the most popular social networks at the moment when the research for the Integrated Decision Making Environment was being done. The reasons behind its popularity has to do with basic human psychology and built-in biological gratification mechanisms driven by self expression and social validation. Facebook offers both means for self expression and social validation.

The reason why Facebook is a very relevant platform for the integrated decision making environment is because it shows how successful social network platforms can integrate and innovate existing technology on the fly, while maintaining strong user growth.

To get a better idea of the technical aspects that are relevant to a large scale social network platform we will use information published by some senior Facebook developers:

Facebook's current architecture is:

- Web front-end written in PHP.
- HipHop Compiler converts it to C++ and compiles it using g++
- Custom build HipHop Interpreter and HipHop Virtual Machine that translate PHP code to HipHop ByteCode
- Thrift for business logic exposed as services. The services are implemented in PHP, C++ or Java

- Custom Java application server. Because the services are only used by Thrift the overhead of other servers like Tomcat or Jetty was too high without adding significant value
- MySQL, Memcached, Hadoop's HBase,
- Memcached for caching MySQL and general purpose cache.
- Hadoop and Hive for offline processing
- Scribe for transiting logging, clicks and feeds data, that's aggregated and stored in HDFS using Scribe-HDFS, thus allowing MapReduce to do extended analysis
- Custom technology to accelerate page rendering using a pipelining logic, it's called BigPipe
- Varnish Cache is used for HTTP proxying
- Haystack and ad-hoc storage for storing photos.
- Standalone architecture for Facebook Messenger
- Facebook Messenger based on infrastructure sharding and dynamic cluster management
- Business logic and persistence is organized in 'Cell'. A 'Cell' handles a part of the users and new Cells can be added as traffic grows.
- Facebook Messenger persistence using HBase.
- Facebook Messenger search engine built with inverted index stored in HBase
- a custom storage and retrieval logic for typeahead search uses
- Epoll server developed in Erlang for Chat and accessed using Thrift

## **Strengths**

Facebook managed to maintain very good quality of service while at the same time having very strong user growth. The Facebook social network is a very good proof of concept for demonstrating how addressing basic human needs, like connectivity, self expression, social validation, will translate to financial success and popularity.

Another important feat that Facebook has done is optimize the web ecosystem and added a plethora of methods and technologies that makes scaling and creation of large web apps way easier, like React, React Native, Relay and GraphQL.



## **Weaknesses**

As we can see from the technical aspects of the platform, the complexity and costs of maintenance is quite huge. Because the platform is a commercial one, and privately owned, the software and hardware architecture had to be custom built.

Another problem with the Facebook is the lack of transparency when it comes to how/which user data is stored, thus allowing the company owning the platform to use that data for purposes outside the scope for which users have shared it.

Although the Facebook platform is very successful and popular, it doesn't offer much when it comes to social governance and decision making. Most of the information circulating inside it can't be centralized in a meaningful way.

## **2.3 Wikipedia**

The Wikipedia platform is supported and hosted by Wikimedia Foundation and it can be freely accessed by anyone on the internet. The people that can access the site will be able to edit articles following established protocols and website policies. Wikipedia is one of the top ten most visited websites on the internet and is the largest and most popular general reference work.

Wikipedia is considered a “resounding success story” as a collaborative system where people can freely participate.

It is still to be determined whether if the success of Wikipedia resulted from the wisdom of the crowds or it was based on a small number of elite users that did most of the work. The data suggests that the success was achieved mainly because of a small number of committed and knowledgeable users and only recently there was a shift towards a greater participation of common users.

Because the users don't have to pay any fee or even register to participate in adding or consuming content allowed for a solid foundation that assured rapid user growth.

One of the key strengths of Wikipedia lies in the contributions of new users that make few edits, which suggests a kind of wisdom of the crowds effect where more and more people are making small contributions to improve quality. Even so many prolific Wikipedia users argue that only a small number of users rather than the masses are the driving force behind Wikipedia's success, so that more than half of the content was added or edited by only 2.5% of the users.

Although Wikipedia hosts a very large platform with millions or even billions of users it is not a commercial company, thus all funds for hosting, development and maintenance comes from user donations.

One aspect that's important to us is the Wikipedia servers architecture and infrastructure. Because as free-access platform it's very important to have a very scalable and cost efficient infrastructure and architecture. As it can be seen from the data disclosed by the Wikipedia foundation they rely on a very well thought, robust and cost efficient architecture.

### Wikipedia Architecture

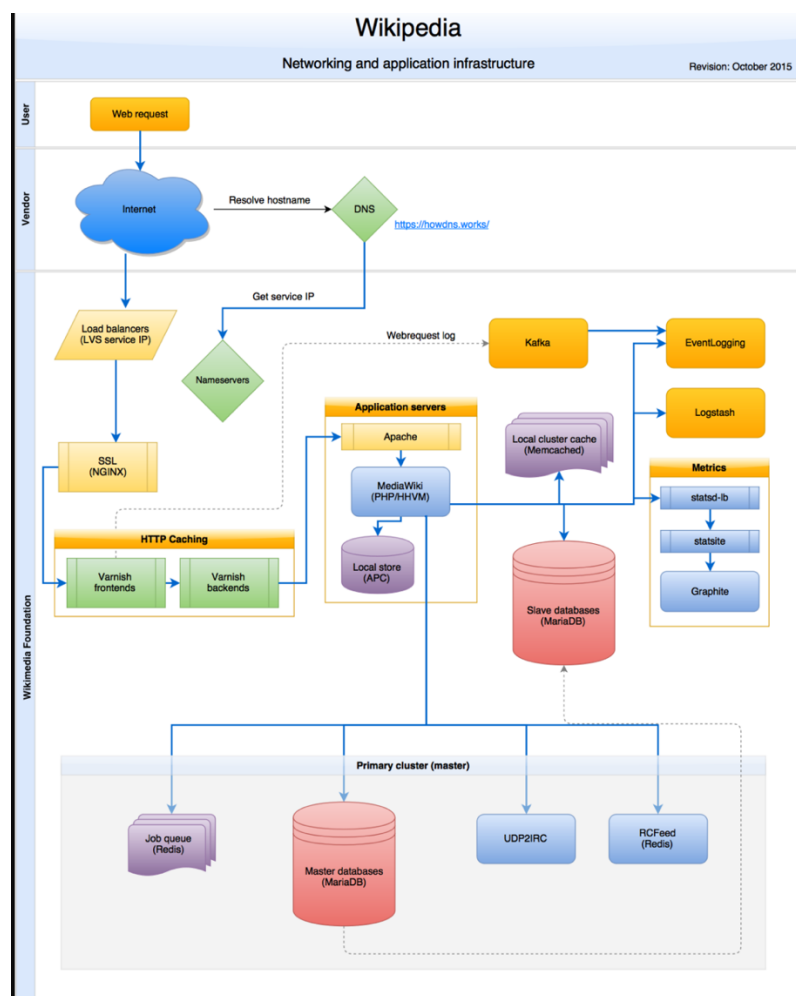


Fig 3. Wikipedia architecture diagram

Wikipedia and the other Wikimedia (Fig 3). projects are run from several racks full of servers.

The Wikipedia architecture as described on their wiki page[21-22]:

- DNS servers run gdnssd. They use geographical DNS to distribute requests between our four data centers depending on the location of the client. (3x US, 1x Europe)

- Linux Virtual Server (LVS) are used on commodity servers to load balance incoming requests.
- Varnish caching proxy server in front of Apache HTTP Server for regular web requests
- Debian or Ubuntu on all servers.
- Swift for distributed object storage
- Code written in PHP 70% and Javascript 30%
- 
- MariaDB for storing structured data, wikis are grouped in clusters, each cluster served by MariaDB servers replicated in single-master configuration
- Memcached for caching data
- ElasticSearch for full text search

### **Strengths**

Wikipedia is one of the first platforms to really centralize the wisdom of the crowds and freely offer it to the world. Based on this principle the platform has grown in popularity very fast and it now covers pretty much every topic of public interest, ranging from social issues to highly technical scientific articles. Any decision making and governance platform should also provide this level of information accessibility using which users can make educated suggestions which are very important in improving the quality of the collective decision being made.

### **Weaknesses**

The greatest weakness of Wikipedia is the fact that the information stored in it is somewhat biased. Because the assigned moderators of important issues are people that follow certain political agendas in conformity to the organization owners, the information being shown there isn't very pertinent when searching for the truth. If the truth is something that goes against the interests of the owners of the organizations it is most of the time censored or unclear information is being given to obfuscate it.

Another weakness that's noticeable from the technical description is the high level of complexity of their architecture, because the servers aren't using a decentralized database, that would at the same time fix the first issue we mentioned, a lot of caching servers need to be distributed around the globe in order to make the data accessible to everyone. This wouldn't happen if the data was being stored using blockchain technology.

## 2.4 Reddit

One of the best content aggregation social networks out there is Reddit. One of the things we want to analyze when it comes to this platform is the algorithms that are used to highlight the relevant content submitted by users despite the high number of content that is submitted every day. The reason the Reddit algorithms are so important to us is that they mimic the way the human central nervous system filters and prioritizes messages coming from the outside and within the body using ganglions. The human ganglions behave like the Reddit platform so that outside signals with a high degree of criticality gets sent to the brain while irrelevant outside stimuli gets ignored by the conscious mind and just pass to the autonomic nervous system.

For this we will use a passage from one of the best online articles describing the Reddit platform: [16]

Reddit is open source, implemented in Python. The sorting algorithms implemented in Pyrex The story algorithm, also called the hot ranking is implemented like this:

```
from datetime import datetime, timedelta
from math import log
epoch = datetime(1970, 1, 1)
def epoch_seconds(date):
    """Returns the number of seconds from the epoch to date."""
    td = date - epoch
    return td.days * 86400 + td.seconds + (float(td.microseconds) / 1000000)

def score(ups, downs):
    return ups - downs

def hot(ups, downs, date):
    """The hot formula. Should match the equivalent function in postgres."""
    s = score(ups, downs)
    order = log(max(abs(s), 1), 10)
    sign = 1 if s > 0 else -1 if s < 0 else 0
```

```
seconds = epoch_seconds(date) - 1134028003
```

```
return round(sign * order + seconds / 45000, 7)
```

In mathematical notation the hot algorithm looks like this [54][56]:

Given the time an entry is posted  $A$  and the time  $B$  we have  $t$ , as their difference in seconds

$$t_s = A - B$$

and  $x$  as the difference between the number of upvotes  $U$  and the number of down votes  $D$

$$x = U - D$$

where  $y \in \{-1, 0, 1\}$

$$y = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$$

and  $z$  as the maximal value, of the absolute value of  $x$  and 1

$$z = \begin{cases} |x| & \text{if } |x| \geq 1 \\ 1 & \text{if } |x| < 1 \end{cases}$$

we have the rating as a function  $f(t,y,z)$

$$f(t_s, y, z) = \log_{10} z + \frac{y t_s}{4500}$$

### Effects of submission time

Submission time related to story ranking:

- the algorithm ranks the stories that are newer higher than older ones
- the score doesn't decrease in time but new stories get higher scores.

For a better understanding we can look at the following graph that shows a story having same amount of votes but different submission times:

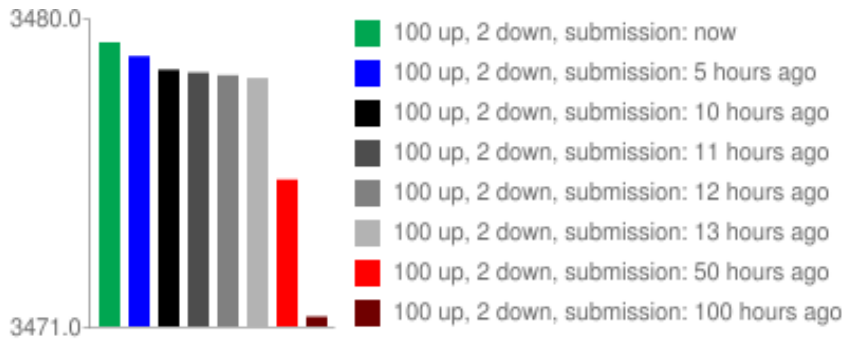


Fig 4. Story Graph for different submission times

### The logarithm scale

In order to rank the first vote higher than the rest the ranking algorithms the logarithm function is being used. This means that the first 10 votes have the same weight as the next 100, which weight the same as the next 1000, etc. [14-15]

Here is a visualization (Fig 5):

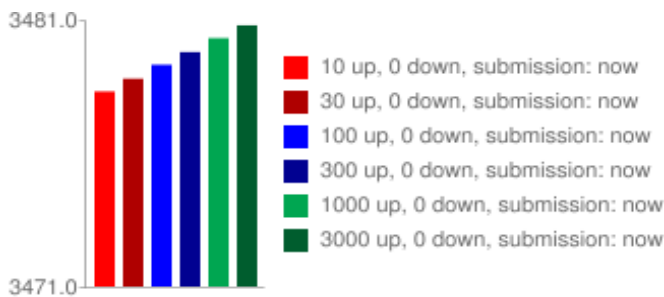


Fig 5. Graph representing weight of the first votes

If we don't use the logarithmic function the score looks like this (Fig 6):

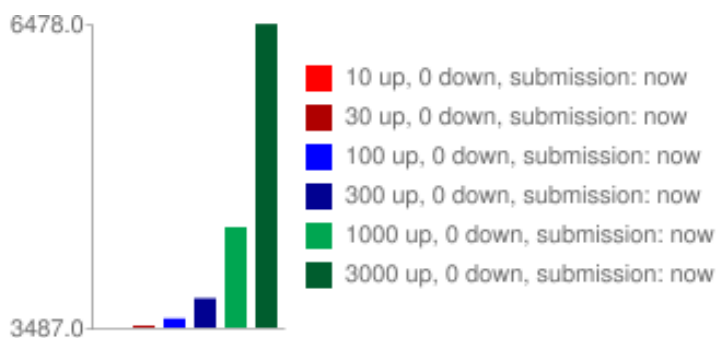


Fig 6. Vote weights graph without using logarithm scale

## Effects of down-votes

Reddit also has the possibility to down-vote. The score is calculated as upvotes – downvotes

This can be better explained in a graph(Fig 7):

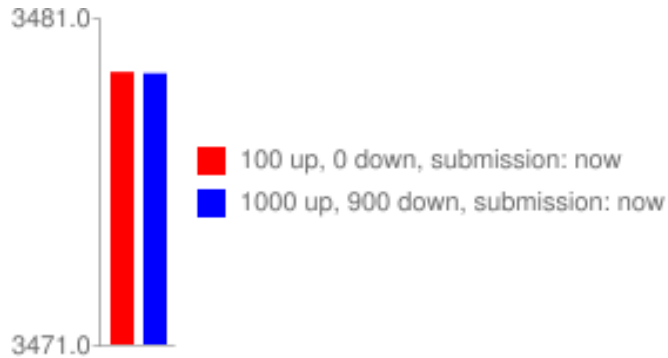


Fig 7. Graph showing same calculated vote for different up/down votes count

Having down-votes results in having controversial posts ranked lower than posts that had only up votes.

## Conclusion of Reddit's ranking algorithm

One of the most important parameter is the submission time so that stories that are new will be ranked higher than old ones. Also the first 10 votes count as much as the next 100, which count as the next 1000 and so on because of the logarithm function. Posts that get a lot of upvotes are ranked higher than those that get even more upvotes but also a lots of downvotes. So that stories with 100 upvotes could be ranked higher than stories that have 1000 upvotes and 950 downvotes.

## How Reddit's comment ranking

The author of the comment ranking algorithm is Randall. He mentioned the following about the comment ranking algorithm:

- the hot algorithm isn't good for comments because it relies too much on the time a comment was posted
- best comments should be ranked first regardless of submission

The solution used for this has been discovered by Edwin B. Wilson in 1927 and it's called "Wilson score interval".

The Wilson's score interval can be used as a "confidence sort"

The number of votes is considered to be a statistical sampling of a hypothetical full vote by everyone, similar to an opinion poll.

### The comment ranking code

The confidence sort written in Python [53][54][56]:

```
from math import sqrt

def _confidence(ups, downs):
    n = ups + downs
    if n == 0:
        return 0
    z = 1.0 #1.0 = 85%, 1.6 = 95%
    phat = float(ups) / n
    return sqrt(phat+z*z/(2*n)-z*((phat*(1-phat)+z*z/(4*n))/n))/(1+z*z/n)

def confidence(ups, downs):
    if ups + downs == 0:
        return 0
    else:
        return _confidence(ups, downs)
```

The Wilson score interval mathematical notation looks like this:

$$\frac{\hat{p} + \frac{1}{2n} z_{1-\alpha/2}^2 \pm z_{1-\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n} + \frac{z_{1-\alpha/2}^2}{4n^2}}}{1 + \frac{1}{n} z_{1-\alpha/2}^2}$$

The meaning of the parameters are:

- $p$  - observed fraction of positive ratings
- $n$  - total number of ratings
- $z_{\alpha/2}$  is  $(1-\alpha/2)$  quantile of standard normal distribution



In layman's terms the confidence sort does the following: treats the number of votes as a statistical sampling of a hypothetical full vote by everyone, gives a comment a provisional ranking with 85% probability it will get to, the confidence score will get closer to 85% the more votes we have.

Here's a screenshot of how the website looks at the time of writing(Fig 9):

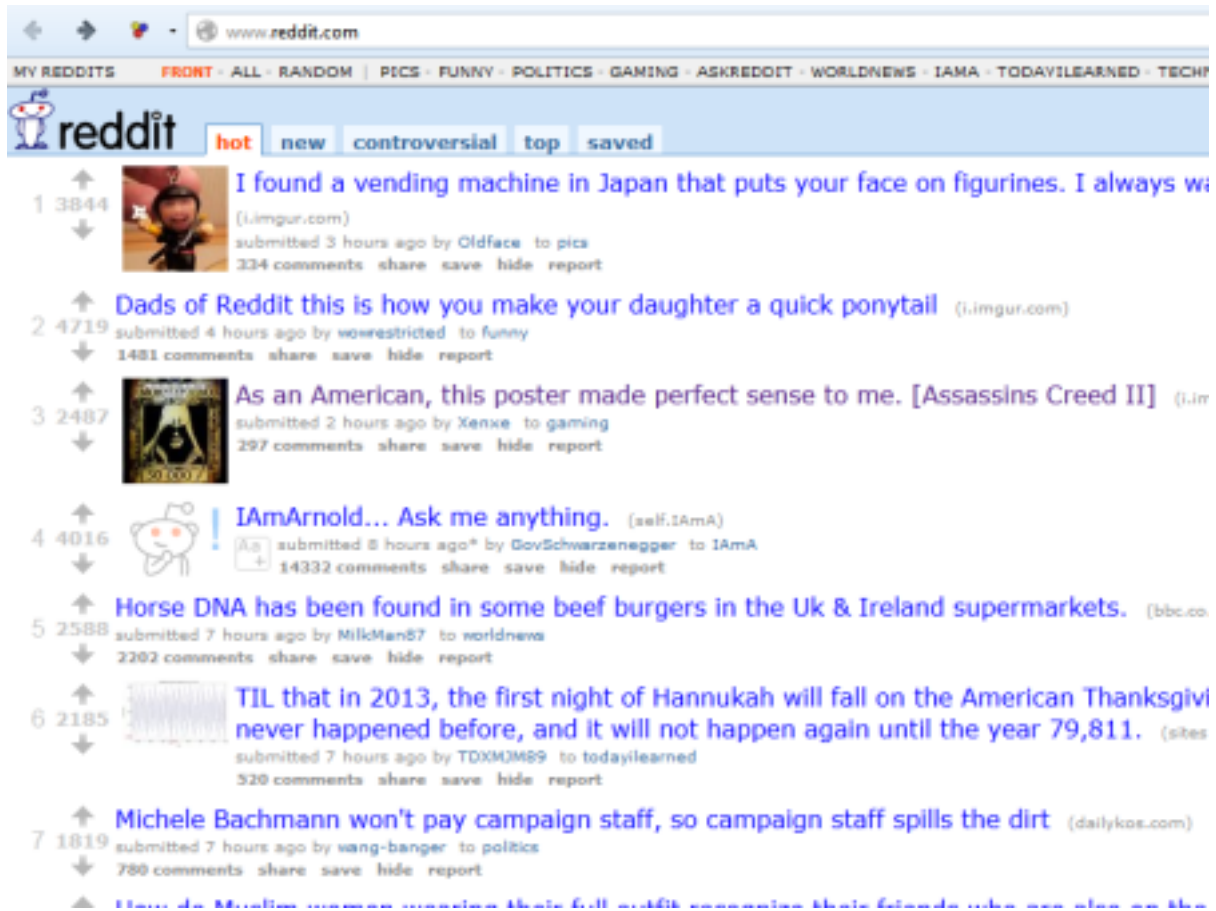


Fig 9. Reddit GUI – www.reddit.com

The content of the website, more specifically the links and the order they are in, change depending on the time you visit. This allows for the website to always have fresh content and news.

The algorithm that allows this to happen works in the following way:

- every post is assigned a number given by the function:

$$f(n, t) = \log_{10}(n) + \frac{t}{4500}$$

In this formula n is the number of up-votes, so for 10 up-votes and 0 up-votes n would equal to 10. For 100 up-votes and 90 down-votes n would equal to 10 as well. The time, t, is the time in

seconds after a certain moment in 2005. The function  $f(n,t)$  computes a score for each link and that score is used to sort them from largest to lowest.

Because the equation is only used to generate the sort order an overall multiplicative factor doesn't change the end result. If a score of 30 is ranked ahead of 15 then 300 will be ranked above of 150. Because of this we can multiply the equation by 45000 seconds:

$$f(n, t) = 4500 \log_{10}(n) + t$$

This means that the posts are ordered by  $t$ , the time when they are posted, so new posts show up higher. The term  $\log(n)$  moves the posts forward in time. That means that new posts are listed first but also that they become newer when receiving up-votes.

If  $n = 10$  then  $\log(10) = 1$  so the post is moved forward by 45000 seconds. If  $n = 100$  then the post is moved forward 9000 seconds. The plot(Fig 10) for this function looks like this:

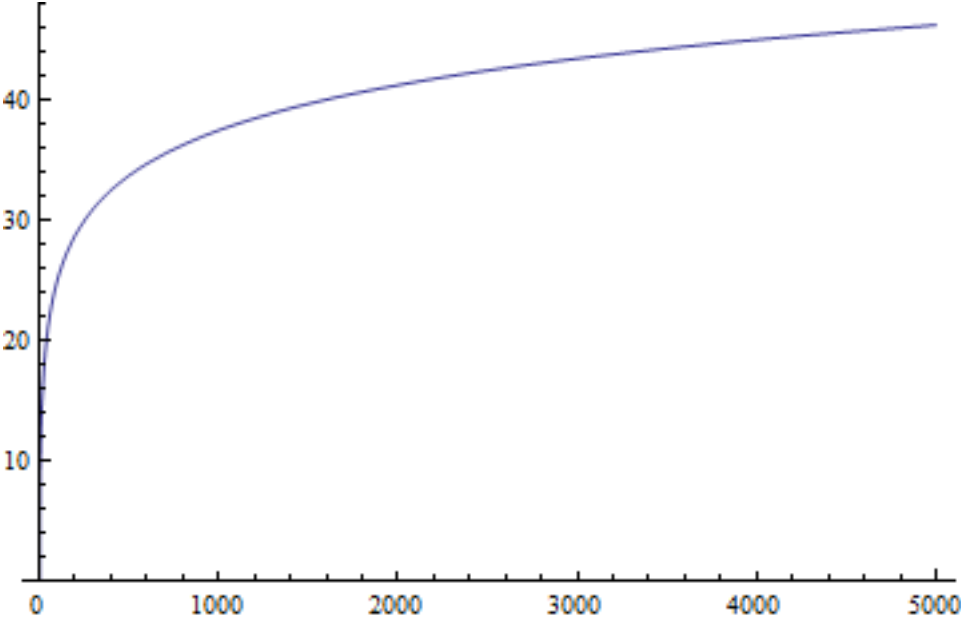


Fig 10. Hours added as a function of net up-votes received

Logarithms are increasing very slowly so new up-votes move a post forward in time by smaller and smaller amounts. Even at thousands of votes a post can only move forward in time about a day or two, after that new posts take the top positions.

We can calculate exactly how much a vote counts. For a large  $n$  we can very accurately approximate the change of  $\log(n)$  by its derivative:

$$\log_{10}(n + 1) - \log_{10}(n) \approx \frac{0.434}{n}$$

The 0.434 value is because the algorithm uses a base 10 logarithm, if e was used then it would have been  $1/n$  instead. What the formula shows is that if your post gets 10 votes you will get  $45000 * 0.434 / 10 = 1727$  seconds (29 minutes) of movement forward in time. If a post gets 50 votes a new up-vote or down-vote will only influence the end result by only 5.7 minutes.

For a post that has 4700 votes like the one in Fig 10, a new vote will only move the time by 3.7 seconds.

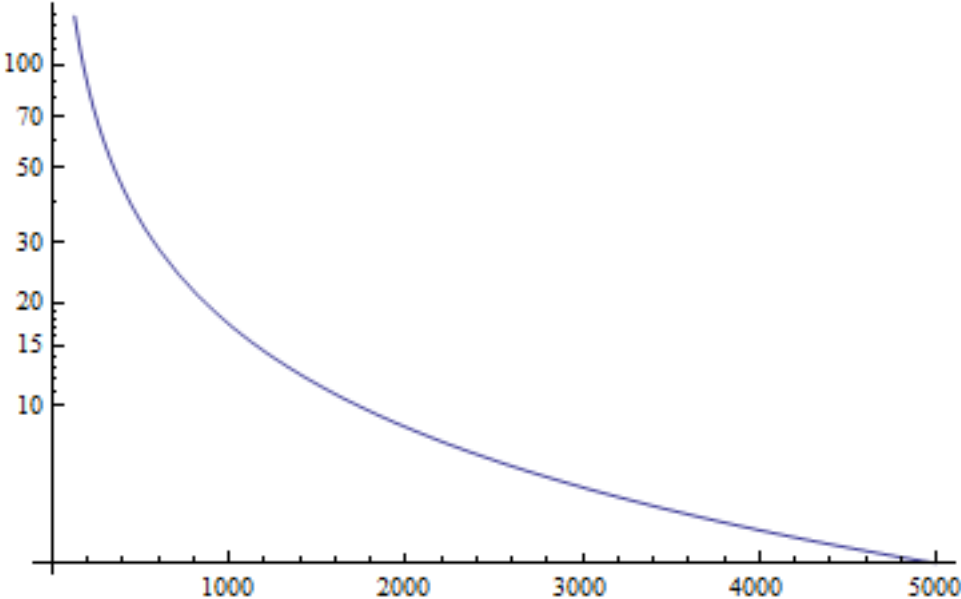


Fig 11. Seconds added (or subtracted) for each additional up-vote (or down-vote), as a function of net up-votes received so far

Compared to most other user-vote based rankings Reddit is very interesting from a mathematical standpoint (Fig 11). [17] [18]

**Strengths**

Although very intuitive and simple to understand, the algorithms Reddit uses to sort and prioritize their content sets them apart from the rest of the news aggregation websites in terms of content relevance and speed of emergence for new critical information. One of the consequences of using naturally occurring algorithms such as the ones Reddit uses was the fast user acquisition because most people prefer to to have the content already sorted for them and only the most critical and pertinent information should reach them.

## **Weaknesses**

An important issue that can occur with the current Reddit sorting algorithms, according to some recent studies, is that the first single up-vote can influence the final decision by up to 25%.

Another issue with the current algorithms is the fact that all users have equal voting power, that means that the system can be affected by spam bots or collective ignorance such that false or irrelevant information can reach the top.

In order to solve both these issues we will be using weighted votes and at the same time give access to new information relevant to the decision making process to all members at the same time.

## **2.5 Existing Blockchain Implementations**

### **Bitcoin**

The first blockchain implementation that became popular was bitcoin. The reasons why this happened are the following:

- Developers were intrigued by the new technology which offered them social recognition, an increase in value from tokens they were holding and the power to influence the future of this technology
- Miners were compensated by the fees that were associated with bitcoin transactions, so every time a new block was mined a certain amount of tokens were attributed to the node that mined that block, the ever increasing value of the virtual currency
- Users were interested in the profits they can make from the increasing value of bitcoin holdings, also the possibilities the virtual currency offered were a great incentive because now they could buy anonymously on the internet and the transactions were instant, no more need to wait for a few days for the money to be sent or arrive

The people involved in developing and promoting bitcoin were coordinating using classical methods like mail lists, and mostly off-chain medium. Developers were using Bitcoin Improvement Proposal process and a mailing list for the communication of new ideas to be developed. Miners can use the chain that they are creating to coordinate with each other. The way the checks and balances system is created is similar to how a government works, which brings a few benefits.

Developers submit pull requests, using version control software, just like the senate submits new bills. The miners decide if they want to adopt the new laws similar to the judiciary branch and the nodes of the network can decide if they will run the same software as the miners or not, just like the executive branch. The users of bitcoin, just like regular citizens can revolt.

The economic incentives require that the trust in the system has to be maintained and in doing so everyone has things to gain. If the users would be put off by the miners then the value of the tokens would decrease and eventually the system would collapse.

The new blockchain platforms that are currently in development will allow for easier coordination by allowing on-chain governance (Fig 12).

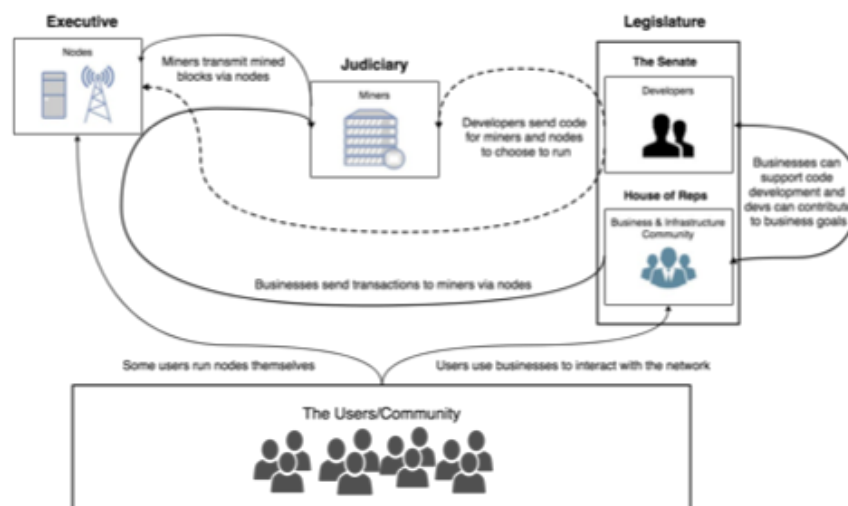


Fig 12. Blockchain Governance

## Tezos

Tezos (Fig 13) allows everyone to submit changes to the governance structure by using code updates. After an update is submitted a vote will happen on-chain. If the vote passes the update is then forwarded to the test network. When enough time has passed for the new code to be tested another on-chain vote will happen that will allow for the code to be passed to the main network. This concept was called self-amending ledger.

Using a system of this sort shifts the power away from more centralized groups of developers and miners towards the users. Any developer can now submit a change and get an economic incentive out of doing it. The people that contribute receive rewards in the form of new minted tokens. This mechanism creates a shift from existing Bitcoin and Ethereum system where the new developers have very little influence and incentive to evolve the code, thus the power is concentrated among existing developers, to a system where everyone has equal power and

personal interest to participate. This also allows users to participate and coordinate directly using on-chain method so that we see a huge increase in their power and a reduction in the influence of miners over the system like it happens in Bitcoin or Ethereum. [19]

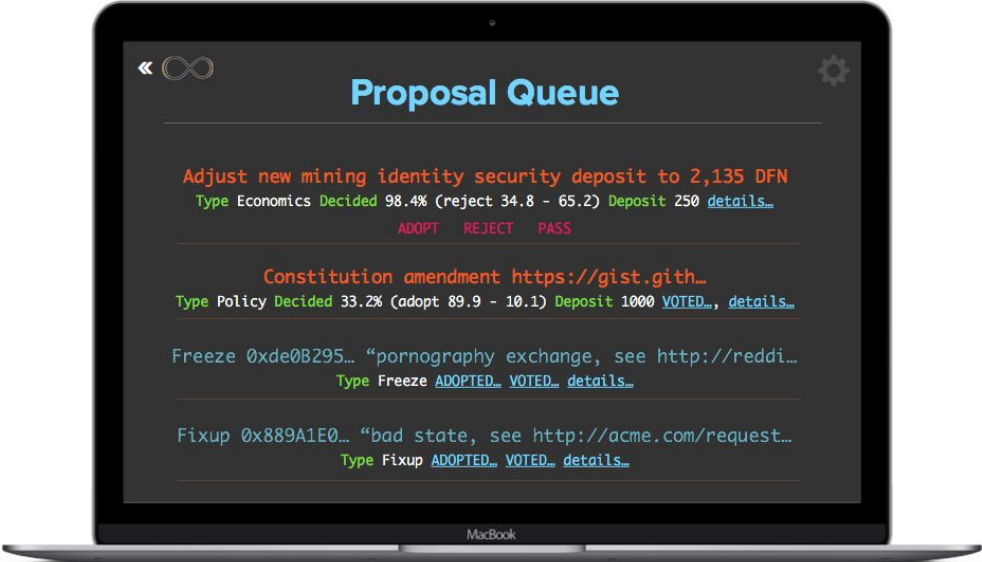


Fig 13. Tezos collaborative policy creation

**DFINITY**

Another step further for on-chain governance is made by DFINITY. In this system users can have on-chain votes for the rules of the system and retroactive changes are made to the ledger itself. That means that token holders can roll back or edit the ledger in case things happen that they don't like, on top of the rules they have to govern themselves. DFINITY was created as a reaction to a massive hack on the bitcoin network that led to millions of bitcoins being stolen. DFINITY allows for things like this to be reversed so the need of a hard fork disappears. In case a hack would happen and tokens would be stolen people can just vote to undo the hacked transaction and all tokens would be recovered. The disadvantage would be that using this system people can lose their tokens if others vote this to happen. This is also possible with existing block-chains, like what happened with Ethereum when the DAO hack happened. They had to do a hard fork in order to reverse the hack and recover the lost tokens. DFINITY has a very high degree of flexibility, it's possible with protocol change to completely rewrite the ledger. Because of this the voting thresholds for different changes will be very different, in some cases requiring a super majority and just a simple majority in other cases. [19]

## **Futarchy**

In futarchy the society defines its values and in order to decide the best course of action tries to predict the markets so those values are maximized. So people vote on values and bet on beliefs. This system was proposed by economics professor Robin Hanson of George Mason University in 2000.

In another relevant proposal Ralph Merkle, in his paper called DAOs, Democracy and Governance, talks about a blockchain implementation of futarchy where users are going to be polled every year and asked about how satisfied they are on a scale from 0 to 1 of the previous year. In order to get an overall societal welfare score we just average together those scores. Based on this welfare score a prediction market can be developed for every year. Averaging the scores for the next 100 years would allow for an overall future welfare score to be calculated, where early years are weighted more than future years. When new bills are proposed there will be a 1-week period where people can discuss whether the overall score will increase or decrease if the bill is passed. If the bill passes the traders that voted that the overall score will go up will own the overall welfare contracts so that if they were right they will make money but they will lose money if they are wrong.

The system offers a few things that could potentially make it very powerful, the first one is that voting becomes really simple, that's because people don't need to vote but are only asked about how satisfied they are every year. Also people don't need to be knowledgeable of candidates or bills, this is a great advantage over other systems because bills can be very complex so that even experts in certain domains have trouble understanding them, and candidates could be very convincing without actually bringing any value. The system instead relies on the wisdom of the markets, so that only people that actually know what they are doing will bet on different topics in order to gain profit. If people aren't informed when voting on certain topics they will lose money. Another important thing of the futarchy platform is that the market incentives are actually aligned with the values of society, so future developments will reflect those values. The problems the system is confronted with is people abusing their votes, like voting 0, in order to influence future policies. [19]

### 3. Decision Making Support

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The domains I have reviewed and offer important information for this thesis are: psychology, anatomy, biology, genetics, computational neuroscience, history, religion, quantum physics, physics, chemistry, and human computing. [4] [2] [1] [20]

Some of the conclusions I reached during my research are:

- a. nature has all the solutions built-in, for those that have the necessary mental containers to extract and understand them, in that regards the world and reality in general can be seen not only as an organic and physical phenomena but also as an informational entity that through its subdivisions can self describe itself
- b. there are no coincidences, the order within can be observed in the order without
- c. technology modeling natural anatomical mechanisms already present in the human body exists in partial form as online platforms like Wikipedia, Facebook, Reddit, etc
- d. human consciousness transcends and controls its physical state
- e. neural connections are like tools or pattern containers that the evolutionary forces of nature uses to help us make sense of what we already know and guide us in the direction we want to go
- f. emotions we create come back to us to create a feedback loop, with the purpose of identifying and optimizing the neural connections that made them possible
- g. consciousness works like an operating system
- h. the nature of evil can be translated into a deterministic psychological structure maintained by faulty neural connections created over our individual evolution
- i. our brain takes part in influencing the collective consciousness and our ideas spread around the planet like an impulse is broadcasted over a network
- j. all information is relevant once the truth is found and information processing is going to be one of the most important fields of study in the future
- k. the heterogeneity of life is perfected once each individual is connected with his built-in purpose and finds meaning in his life by expressing his innate individuality.
- l. essentially there are no contradictions between spirituality/religion and science, only little minds that can't fit them together
- m. humans encouraged to live and express their individuality will resemble puzzle pieces that will perfectly fit together, without glue holding them together, in contrast to a conformist philosophy which creates bricks out of people, through forced conformity, and holds them together using concrete (fear of unconformity maintained through manipulation and intimidation)
- n. the nature of God is physical Wisdom (Perfect Cognitive Coherence, which can be perceived by the mind using the brain, that permeates and orders all physical dimensions) and Love that transcends time and space and it's found within all living beings and it's the driving force of evolution



### 3.1 Swarm Intelligence for Decision Making

The decision making process of a honeybee swarm is very similar to the brain. Both the brain and a bee swarm are made up of large populations of excitable units, bees and neurons, that work together in parallel with the purpose of integrating information with a certain amount of uncertainty, weight and compare different alternatives and unanimously come to a singular decision. In order for a final decision to be made the population forms a closed loop where subpopulations compete in real time, while each subpopulation supports their own different alternative. The decision is made when one of the alternatives reaches a certain threshold of support compared to the other alternatives, and the threshold level doesn't need to be unanimous nor even a simple majority, but just a sufficient quorum that manifests a certain amount of excitation.

In biological brains we have integrator neurons that have the purpose of summing up the activation of supportive units and at the same time inhibit competing units. Combining activation with inhibition signals allows the brain to not get into a deadlock so an optimal decision is reached. The same behavior was seen to be performed by honeybee swarms where activation and inhibition signals are combined in order to make the optimal decision and avoid deadlocks. [7] [21] [22]

Each year during spring the honeybee swarms need to make a collective decision of selecting the best place for a new colony. For this the oldest and most experienced scout bees search a large area and bring back alternatives to the swarm. They try to influence and convince the swarm about the location they found by using body vibrations, referred to as "waggle dance". Using these body vibration the bees also send out information about the location of the new colony site, like distance or direction. Using this special dance honeybees can also transmit inhibiting signals to other bees. Using this method a closed loop feedback control is created that uses both excitation and inhibition, so just like neurons the honey bees create a closed-loop dynamic system of units working in parallel, where each bee supports other bees that prefer the same alternative and inhibit the ones that want different alternatives. When a sufficient quorum of highly excitable units is reached the decision is made. Using this method the honeybee swarm can select between dozens of alternative colony sites spread across 30 square miles, while evaluating each alternative based on multiple criteria.

Because the decision of selecting a new colony is not one based on isolated voted, but made through live negotiation of different alternatives as a group, the place they end up using usually

is the one that best satisfies their requirements. By not using a voting system the result isn't the one that's most popular but the one that's best for the group. Real-life negotiation where many alternatives are considered and participants are interacting in synchrony to inhibit and excite others allows for the best solution to be chosen so that the group satisfaction is maximum.

When making decisions in a human context we can't rely on the quality or enthusiasm of someone dancing to trust them, but instead we can find the human equivalent of the bee dance that would allow us to trust that person.

The human mind is capable of understanding the passing of time and at the same time, using our memory, see someone's life as a static picture. This static picture we can create in our minds of someone's life can be considered their dance based on which others trust their judgment and the alternatives they are proposing.

Just like how a bee swarm chooses the next harvesting location indicated by the bees with the best dance form and enthusiasm, so can humans give more trust to individuals that display the highest human values during their dance through space and time. Because of our fractal nature we can rely on the property of self similarity and trust that a person that did well in their past relationships will do well on their future relationships, not because they are forced by social norms but because it's part of their identity. [7] [22]

### 3.2 Bayesian Decision Making

Bayes' theorem allows us to create relationships between different conditional probabilities. By conditional probability we refer to how probable one event is based on other occurred events, the events that already occurred can be given a fixed value based. For instance, "what is the probability that the altcoin is profitable?" will have a different answer than "what is the probability that the altcoin is profitable given that the creator is Vitalik Buterin?"

For a joint probability distribution for events A and B ,  $P(A \cap B)$ , the conditional probability of A given B is defined as (Fig 14):

$$P(A | B) = \frac{P(B | A) P(A)}{P(B)}$$

Fig 14. Joint probability distribution over events A and B

In this formula  $P(A \cap B)$  is the probability that both A and B occurs, which is equivalent to the probability of A occurring multiplied by the probability of B occurs given that A occurred:  $P(B | A) \times P(A)$ .

We can also say that  $P(A \cap B)$  is the probability of B occurring multiplied by the probability that A occurs given that B occurs:  $P(A | B) \times P(B)$ .

Based on the equality of these two expressions we can put together Bayes' Theorem, which expressed mathematically looks like this (Fig 15):

$$\begin{aligned}
 P(A | B) &= \frac{P(A \cap B)}{P(B)}, \text{ if } P(B) \neq 0, \\
 P(B | A) &= \frac{P(B \cap A)}{P(A)}, \text{ if } P(A) \neq 0, \\
 \Rightarrow P(A \cap B) &= P(A | B) \times P(B) = P(B | A) \times P(A), \\
 \Rightarrow P(A | B) &= \frac{P(B | A) \times P(A)}{P(B)}, \text{ if } P(B) \neq 0.
 \end{aligned}$$

Fig 15. Bayes theorem derived from the definition of conditional probability

The results for Bayes' theorem and our result for dependent events are valid when the events are independent.

That means  $P(A | B) = P(A)$  and  $P(B | A) = P(B)$ , so the expression becomes (Fig 16):

$$P(A | B) = \frac{P(B | A)}{P(B)} P(A)$$

Fig 16. Bayes Theorem

Even though the equation has general applicability over any type of events A and B, the equation has an even better interpretation in the case where A represents a hypothesis H and B represents observed evidence E.

This translates into a relationship between the probability of the hypothesis before evidence  $P(H)$  to the probability of the hypothesis after we get evidence  $P(H | E)$ .

This is why  $P(H)$  is called prior probability and  $P(H | E)$  is called posterior probability.

The factor used to relate the two is called likelihood ratio (Fig 17).

$$\frac{P(E | H)}{P(E)}$$

Fig 17. Likelihood ratio

Based on these terms we can rephrase the Bayes' theorem to say "the posterior probability equals the prior probability times the likelihood ratio"

### **Bayesian Networks**

A Bayesian Network (BN), or belief network, is a probabilistic graph model(GM). Using a BN we can represent knowledge with a certain degree of uncertainty about different domains, each node in the graph is a variable while the edges of the graph represent the probabilistic relationship between the two variables. [12]

In order to estimate the conditional dependencies between the nodes of the graph we use known statistical computational methods. A BN combines different principles from probability theory, statistics, graph theory and computer science. The BN is represented using a structure called directed acyclic graph(DAG) which is very popular in statistics, artificial intelligence and machine learning. BN are mathematically rigorous and also intuitive so using them we can achieve an effective computation and representation of joint probability distribution (JPD) for a set of random variables. The DAG can be defined by two sets, the vertices or nodes and the set of directed edges.

The nodes are drawn as circles and represent a random variable, they are labeled with the variable name. An edge represents a direct dependency between the variables and are drawn as arrows between nodes.

An edge from node  $X_i$  to node  $X_j$  will represent the statistical dependence between the two. An arrow indicates that the value of the variable  $X_j$  depends on the value of the variable  $X_i$ , or in other words the variable  $X_i$  influences  $X_j$ . The node  $X_i$  will be considered the parent of  $X_j$  and  $X_j$  the child of  $X_i$ . These terms can be used to define the set of descendants of a node, which is composed of nodes that can be reached using a direct path.

Because we are using an acyclic graph we know for sure there will be no node that can also be its own ancestor. Without this property of acyclic graphs we wouldn't be able to have a correct representation of the joint probability of a collection of nodes.

Even though an arrow represents a direct causal connection between two nodes (variables), the reasoning process can also make sense of BNs by propagating information in any direction. That means that any variable is independent of its non descendants, given the state of its parents. Because of this property we can reduce the number of required parameters that are needed to represent the joint probability distribution of variables. This allows us to efficiently calculate the posterior probability given the evidence.

The acyclic graph structure is considered to be the qualitative part of the model but we also have quantitative parameters that need to be specified.

The conditional probability distribution (CPD) of each node depends only on its parents, this allows for the parameters to be described in a way that's consistent with a Markovian property. The conditional probability is represented by a table in the case of discrete random variables. The table lists the local probability that a child node takes on each of the possible values for each combination of values of its parents. From a collection of variables we can uniquely determine the joint distribution by using the local conditional probability tables(CPT). [12]

Considering the above discussion we can give a more formal definition to a BN. A Bayesian Network  $B$  is an annotated acyclic graph that represents a joint probability distribution over a set of random variables  $V$ .

The network is defined by a pair  $B = G$ .  $G$  is the directed acyclic graph. The nodes  $X_1, X_2, \dots, X_n$  represent random variables and its edges represent the direct dependencies between the variables.

$G$  encodes independence assumptions by which a variable  $X_i$  is independent of its non-descendants given its parents in  $G$ . The set of parameters of the network is represented by the second component, the set contains the parameter  $\theta_{x_i|\pi_i} = P_B(x_i|\pi_i)$  for each realization of  $x_i$  of  $X_i$  conditioned by  $\pi_i$ , the set of parents  $X_i$  in  $G$ .  $B$  defines a unique joint probability distribution over  $V$ :

$$P_B(X_1, X_2, \dots, X_n) = \prod_{i=1}^n P_B(X_i|\pi_i) = \prod_{i=1}^n \theta_{X_i|\pi_i} \quad (1)$$

### **3.3 Decision Making based on the Human Anatomy**

The Integrated Decision Making Environment is modelled after the anatomy of the human body. The most relevant biologic system in the human anatomy to decision-making is the nervous system.

The nervous system connects the brain, with its two hemispheres, to the rest of the body through the vertebral column and nervous ganglions located around the body. Ganglions, depending on their role, route and filter messages coming from individual cells. A nervous ganglion is a nerve cell cluster or group of nerve cell bodies that has the purpose of intercepting signals coming from the neural cells located around the body, which have the role to sense external stimuli, and after filtering and prioritizing the signals, forwards them to the brain which decides on the action which will be taken according to the received signal.

The human nervous system is already built like the perfect decision-making system and all it's functions can be easily modeled and implemented into a real platform that humans can use to govern themselves as one heterogeneous body regardless of the number of people involved or their individual peculiarities.

The different organs and systems that the human body contains can be found in real life as Departments, Organizations, Corporations, etc, but without a central point of governance these organs act against each other instead of cooperating.

To understand the mechanisms used by the brain when making decisions we don't necessarily need a microscope, as we know from fractal theory, the general consensus is that theoretical fractals are infinitely self-similar and this also applies to natural fractals. The branches of a tree are distributed similarly to the Bronchial Tree that forms our lungs. The fractal form of our lungs isn't similar to the branches of a tree just by coincidence, both play a role in respiration, just how we use our lungs to breath, so are the trees the lungs of the Earth and used for the same purpose. [4]

We also know that fractals aren't limited to geometric patterns but can also describe processes in time. Knowing this we can extrapolate that the same processes and mechanisms used in decision making at a micro-biological level will be self similar to the way swarming insects make decisions for their colonies (bee-hives, ant colonies, etc). In fact there are studies that show that the decision-making processes performed by honeybee swarms and biological brains are remarkably similar in many ways. Based on both empirical and normative evidence we can

identify the natural mechanisms and processes used by nature in handling decision making for large populations of units (neurons, bees, humans, etc). In all cases mentioned above (neurons, honeybees, humans), the problem of decision making can be described in similar terms.

The populations are formed by individual and relatively independent excitable units that work in parallel for the good of their colony or group. The decision making process consists of integrating noisy evidence, weighing competing alternatives and converge on a singular decision.

All individual units possess built in means of communication used to share information with one another and the group. Depending on the species the members express the relevance of the information they hold in different ways using patterns known to the group they are part of. In the case of honey bees the intensity of their body vibration, called 'waggle dance', is a way to signal the amount of enthusiasm for the locations they found. Using these body vibrations they also encode the distance and direction to possible colony sites or pollen harvesting locations. The dance can also inhibit other bees from communicating the locations they found.

### **Central nervous system**

The brain is considered to be the most important organ of the body. It is made from soft delicate tissue that could be damaged very easily, that's why it is very well protected. The brain is located inside the skull and it's the center piece of the nervous system. [23]

The function of the brain is to control the body. The brain is made from many parts, with each part having a specific function. The brain consists of two hemispheres but can also be divided into four areas, the cerebrum, the brainstem, the cerebellum and the diencephalon.

### **Neuron**

The neuron, also called a nerve cell, is an electrically excitable cell used to process and transmit information using electrical and chemical signals. The signals are sent using synapses which are specialized connections with other cells. Many neurons can be connected to each other to form a neural network. The neurons are the main cells that compose the brain and spinal cord of the central nervous system. They also make up the ganglia of the peripheral nervous system.

There are different types of neurons with different roles: sensory neurons, that perceive touch, motor neurons that cause muscle contractions by receiving signals form the brain or spinal cord, sound, light and many other stimuli affecting the cells of the sensory organs that send signals to the brain, interneurons which connect other neurons with each other.

A neuron is made of a cell body, dendrites and an axon. Dendrites are thin structure that come out of the cell, they extend hundreds of micrometers and branch out multiple times creating complex dendritic trees. The axon is special extension that comes out of the cell body at a special site called axon hillock and can travel for a distance of up to one meter. The nerve fibers are bundled into fascicles and in the peripheral nervous system bundles of fascicles create the nerves. The neuron cell body grows multiple dendrites but always only one axon, with the specification that an axon can branch out hundreds of times.

In synapses the signals are sent from the axon of a neuron to the dendrite of another but there are also exceptions to this like neurons that don't have an axon, or don't have dendrites or synapses that connect a dendrite dendrite to another dendrite or an axon to another axon.

Using metabolically driven ion pumps which combine ion channels inside the membrane to generate intracellular vs extracellular concentration differences of ions (like potassium, sodium, chloride and calcium) neurons maintain voltage gradients across their membrane so they are all electrically excitable.

If there are changes in the cross membrane voltage then the voltage dependent ion channels are altered. When the voltage change is high enough an all or none electrochemical pulse (called an action potential) is generated. The pulse travels through the cell's axon and it will activate synaptic connections with the other cells when they are reached.

Neurons in most cases are generated by special types of stem cells and they don't undergo cell division. The astrocytes, which are star shaped glial cells, have been observed to transform into neurons because of the characteristic pluripotency of stem cells. For humans neurogenesis usually stops when reaching adulthood except two areas, the hippocampus and olfactory bulb that still generate large number of new neurons. [24]

### **Action on other neurons**

Neurons can affect each other by releasing neurotransmitters that bind to chemical receptors. The type of receptor that's being activated determines the way a neuron is affected, so the effect of the postsynaptic neuron isn't determined by the presynaptic neuron nor the neurotransmitter.

The neurotransmitter can be compared to a key and the receptor to a lock, with the specification that the same type can key could be used to open many different types of locks. Receptors can have an excitatory role, causing the increase of the firing rate, an inhibitory role, causing a



decrease in firing rate or a modulatory role, causing long lasting effects that are not related directly to the firing rate.

There are two most common neurotransmitters in the brain, glutamate and GABA, and their actions are largely consistent. Glutamate can cause effects that are excitatory at ionotropic receptors and modulatory at metabotropic receptors and they can act on a few different types of receptors. GABA only has inhibitory effects and acts in a few different types of receptors.

Because of these facts neuroscientists refer to cells that release glutamate as being excitatory neurons and cells that release GABA as being inhibitory neurons. More than 90% of the neurons release either glutamate or GABA so the majority of them can be classified as either inhibitory neurons or excitatory neurons. Other types of neurons exist that have consistent effects on their targets. In the spinal cord we have excitatory motor neurons that release acetylcholine and inhibitory neurons that release glycine.

The neurotransmitters distinction between excitatory and inhibitory depends on the class of chemical receptors that are present on the postsynaptic neuron. That means that a neuron that releases a single neurotransmitter can have excitatory effects on some targets, inhibitory effects on some neurons and modulatory effects on others.

The photoreceptor cells in the retina constantly releases the glutamate neurotransmitter whenever there is no light. OFF bipolar cells, like most neurons, are excited by glutamate. Neighboring target neurons, called ON bipolar cells, instead are inhibited by glutamate because they don't have the typical ionotropic glutamate receptor but have a class of inhibitory metabotropic glutamate receptors instead.

The photoreceptors cells stop releasing glutamate when light is present, which causes the ON bipolar cells to be relieved from inhibition thus making them active. At the same time this removes the excitation from OFF bipolar cells making them silenced.

Based on the proteins expressed by the presynaptic neuron we can identify the type of inhibitory effect it will have on the postsynaptic neuron.

## **Connectivity**

The neurons can communicate with each other using the synapses, where the axon terminal of one cell invades the dendrite, some or axon of another neuron. Neurons, like the Purkinje cells that are present in the cerebellum can have more than 1000 dendritic branches, connecting them with tens of thousand other cells. The magnocellular neurons located in the supraoptic nucleus

only have one or two dendrites that receives thousands of synapses. The synapse can either inhibit or excite a target neuron, increasing or decreasing its activity. Some neurons can communicate using electrical synapses which are a direct electrically conductive junction between them.

In the case of a chemical synapse we have the following synaptic transmission process: when the axon terminal receives an action potential, the terminal opens the voltage-gated calcium channels that allow calcium ions to enter the terminal.

When the calcium enters the terminal it causes the synaptic vesicles (small fluid-filled bladder/sac), which store various neurotransmitter molecules, to fuse with the membrane and release their contents into the synaptic cleft. The synaptic cleft is the space between neurons at a nerve synapse across which a nerve impulse is transmitted by a neurotransmitter, its also called a synaptic gap. The neurotransmitters will spread across the synaptic gap and activate receptors on the postsynaptic neuron. When high cytosolic calcium is present in the axon terminal it will trigger mitochondrial calcium uptake that will further activate the mitochondrial energy metabolism and produce ATP that supports continuous neurotransmission.

## **Cerebrum**

The Cerebrum is the largest part of the brain, the front section of the cerebrum, the frontal lobe, is involved in thought, emotions, speech and skilled movements. Behind it we have the parietal lobe that has the role to perceive and interpret different types of sensations like temperature, touch and pain. At the centre back of the cerebrum, behind the parietal lobe, there is a region called occipital lobe that detects and interprets visual images. At either side of the cerebrum we have the temporal lobes that are involved in storing memory and hearing. The cerebrum is split in two halves called hemispheres that communicate with each other. [23]

## **Cerebellum**

The cerebellum is involved in muscle movement coordination and control, enabling muscles to make precise movements, posture and balance.

## **Diencephalon**

The diencephalon contains two structures called thalamus and hypothalamus. The thalamus has the role of relaying incoming sensory nerve impulses and send them to the appropriate regions

of the brain for processing. It's also responsible for letting the brain know what's happening outside the body.

The hypothalamus has the role of regulating the conditions inside the body like, temperature, thirst and hunger and controls the release of hormones from the pituitary gland. [23]

### **Brain stem**

The brain stem has the role of regulating life support mechanisms like breathing, the heart rate, blood pressure and digestion. It also regulates the sleep and awake cycle.

### **Corpus callosum**

The corpus callosum is a wide, thick nerve tract. It consists of a flat bundle of commissural fibers located under the cerebral cortex in the brain. The corpus callosum can only be found in placental mammals. Its role is to connect the two hemispheres and enable communication between them. It's the largest white matter structure in the brain (approximately 10 cm) and consists of 200-300 million axonal projections. Some separate nerve tracts called subregions connect different parts of the hemispheres.

## **3.4 Fractals – the edge of infinity**

A fractal is a never-ending pattern. Fractals are infinitely complex patterns that are self-similar across different scales. They are created by repeating a simple process over and over in an ongoing feedback loop. Driven by recursion, fractals are images of dynamic systems - the pictures of Chaos. Geometrically, they exist in between our familiar dimensions. Fractal patterns are extremely familiar because nature is full of fractals. For example: mountains, clouds, trees, rivers, coastlines, seashells, etc. Abstract fractals – like the Mandelbrot Set (Fig 18) - can be generated on a computer by recursively calculating a simple equation.

Natural fractals include branching patterns like trees, , lightning bolts, river networks, blood vessels, etc., and spiral patterns like galaxies, seashells or hurricanes. A tree grows by repetitive branching.

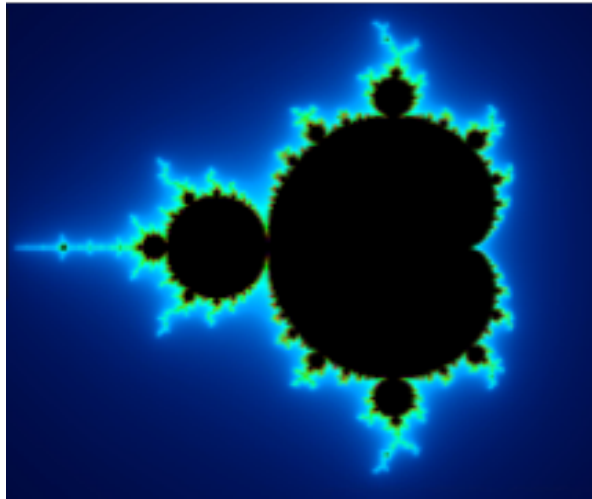


Fig 18. The Mandelbrot set

The body of being(nature/God) speaks in fractals, infinite complexity and meaning expressed in simple forms/formulas. [1]

Using the property of self similarity specific to fractals, we can identify decision making patterns used by nature and apply them to the integrated decision making environment.

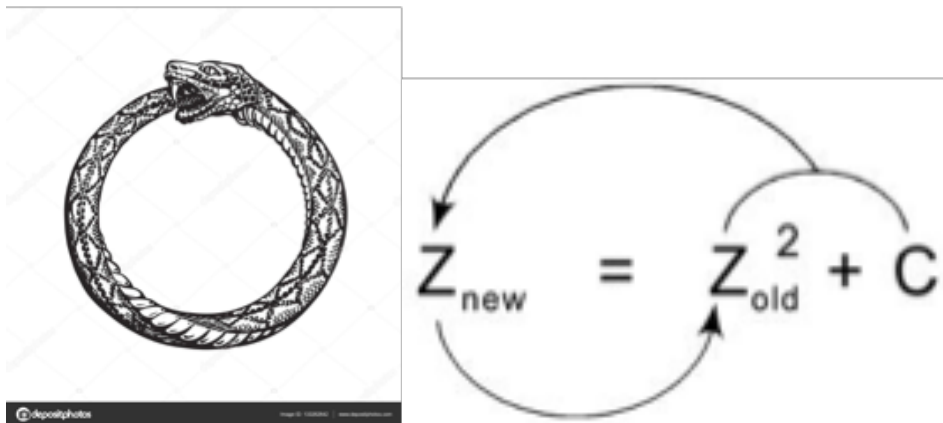


Fig 19. Ouroboros - Self similarity symbol and Mandelbrot recursive formula

The ancient Ouroboros Symbol (Fig 19) encodes the concept of recursion (the snake feeds itself to itself) which is at the base of fractal generated geometry, where the result of the previous iteration become the parameters of the new iteration. Fractals also exhibit the property of evolving symmetry which allows us to find the symmetric equivalent of basic decision making processes found in nature and apply them at different levels within our decision making environment.

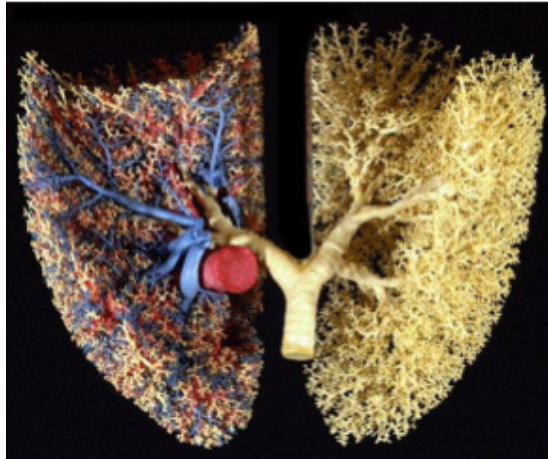


Fig 20. Lungs Fractal

The lungs are an excellent example of a natural fractal organ (Fig 20). You can see that the lungs share the same branching pattern as the trees. And it is for good reason! Both the trees and lungs have evolved to serve a similar function – respiration (Fig 21). Since they perform a similar function, it should not be surprising that they share a similar structure. This common concept in science is known as the Structure-Function Relationship [13]

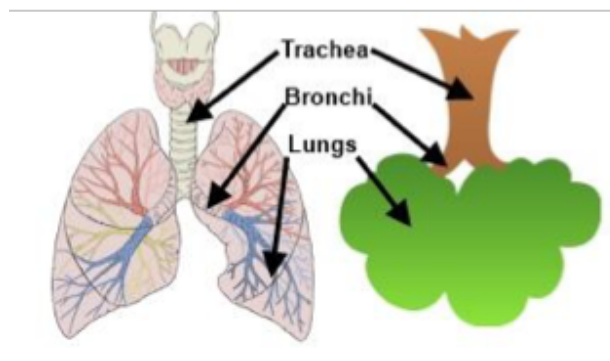


Fig 21. Structure Function Relationship

**Primordial distinctions (male / female)**, seen in our body's anatomy, inspired algorithms and the organization of society, without distinctions identity would have no meaning. We have intuitively applied our anatomical structure and functions into organizing our society, both being the expansion of the same conscious homeostatic fractal.

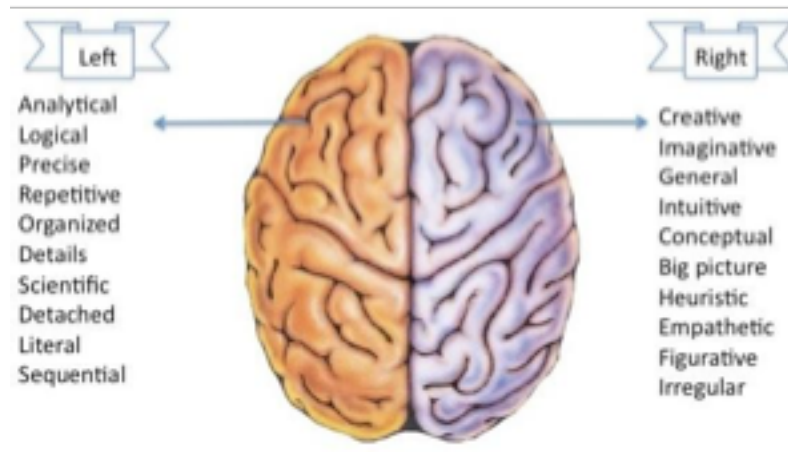


Fig 22. Brain Hemispheres functions

We only recently learned about the different functions of the hemispheres (Fig 22) of our brain but our governance system used these distinctions since it was created (Fig 23).



Fig 23. Branches of Government

At the base of the Integrated Decision Making Environment are a number of natural patterns that the fractal of life uses in places where governance and group decision making is needed like: - the bee swarm, where we can understand the mechanisms of swarm/collaborative decision making as well as methods to integrated distributed knowledge and converge on a final - brain neurons, which make decisions in a similar way with a bee swarm, they inhibit and excite each other to form networks which represent abstract solutions to the problems we are looking for. When the brain makes decisions it doesn't rely on all the neurons, or even the majority of neurons, to converge in a network. Instead a decision is made when only a certain threshold is reached which represents only a sufficient quorum of excitation - from the human

DNA code we gained the knowledge of creating the blockchain, which is a distributed database that allows for the information inside the system to be available to all deciding agents and governed body without actually being centralized and vulnerable to unauthorized changes by the authority in charge of it - the three parts of the brain provided us with the pattern that we used to create the three branched governance system, which was also adopted by the Decision Making Environment - the central nervous system inspired the interface needed for the deciding agents to interact with the govern body as well as the creation of the feedback loop functionality in the form of the Feedback component that uses the felicific formula to assure overall satisfaction for each decision being taken.

### 3.5 Blockchain Decision Making

When we refer to a blockchain, at the broadest level, we usually refer to a network of databases that's spread across multiple entities and are synchronized, where there's no single controller or owner of the data. The databases tend to be append-only, that means they can be written to, however historical data can not be altered without a general agreement from the participants of the network. This implies that a system administrator or user in one entity can not alter data contained on a blockchain without an existing general agreement from the rest of the participants. (Fig 24)



Fig 24. Centralized versus Decentralised Database

Historically, in situations where various parties needed to trust the same data, we've used golden sources of data, controlled and held by third parties that can be trusted. A classic example could be the use of a clearing house as a golden source of data about transactions between two entities. The Blockchain has the option to empower groups of parties to agree on events without the need of a third party, this is one of the key features of this new technology.

In cases where there is a low level of trust, caused by differences in regulatory and operational landscapes, for instance in multi party cross border transactions, the transparency given by the blockchain could be useful, making the lack of trust not a problem anymore, in these kind of interactions.

### **Resilience**

The resilience of the data can benefit from storing data over a large number of nodes – the data becomes more robust as the the number of blockchain participants becomes larger, and also has a longer lifespan. Looking from this perspective, a blockchain system is similar to a massive replicated database.

### **Efficiency**

An improved efficiency can be seen when blockchain technology is used by financial entities to reconcile trades. Usually a bank will choose one of its own systems as the golden source of trade data for any particular resource. The chosen golden source could be a commercial solution or an in-house built system. In order to use your own system as a golden source and at the same time allow it to reconcile and synchronize with other industry third party or trading counterpart requires a lot of effort and it can be very inefficient due to system incompatibilities and processes. In these cases the reconciling is done using the best common technology and results in end-of-day batch files.

Using a blockchain means having the agreed trade data already in-house, so the need for external reconciliation is removed, as the blockchain does this in real time. Payments between financial entities could also be sped up by using blockchains. Using the blockchain's capability to store data we can use „if-this-then-that” logic in code snippets to automate one day payments and messages. If the payoffs can be agreed upfront by the parties (commonly this is agreed in term sheets, that are written in dry legal language) and the trade details can be encoded in the payoff terms, when trade lifecycle events happen we can see efficiencies in the form of speed increases and error reduction. The name for the codes snippets commonly used in blockchains is “Smart contracts”. [15] [14]

### **Transparency**

Regulators, or other parties that are interested, can plug into a common platform, that contains published trade data, and get a live view of the trades. This way, an oversight is given to the regulators using this common data source, becoming more efficient than receiving different



reports in diverse formats and at different times, and also from different institutions. This way, system risks could be detected sooner because of the transparency offered by blockchains.

### **Governance and Trust**

In a blockchain system the majority of participants have to agree on the data being added, before it can be incorporated in the definitive blockchain. This is quite different to central, often secretive ledgers held and controlled centrally. A more honest system can be created when the ability to write, alter or remove dubious data depends on multiple parties. Land registry systems can be given as an example. Records can be easily modified by a database administrator, when the data is held centrally, and also their tracks can be covered without anyone noticing. When a blockchain system with multiple participants (like NGOs, regional government, local government and perhaps other government branches) contains a land registry, to make a change to a record multiple parties would have to agree, and the questionable changes could be immediately identified, and not be approved without the majority.

### **Event recording**

If we move away from the term ‘ledger’, with the financial connotations it brings, we can also use the blockchain to record events. An event might be any kind of data that can be encrypted or recorded in plain view. Example of events in financial services could represent a lot of things, from meeting minutes to shareholder votes, messages between entities to documents, counterparty data to industry-agreed FX settlement of holidays.

The protection gained from using a blockchain is that the data can not be edited once written, and has a trusted timestamp, without relying on an independent trusted third party. The data stored on the blockchain is protected, without relying on an independent trusted third party, by a trusted timestamp, so it cannot be edited once written.

The Blockchain technology and space are new, and as such there are many different ways to understand blockchain systems and terminology has yet to be standardised.

### **How the Blockchain works**

In its most basic form the blockchain is a shared, replicated, append-only database. Write access is shared among some participants, but validation is performed by all participants.

The most common elements on a blockchain systems are:

- A data store that can contain any type of data, but usually it contains financial transactions, replacing a classical ledger
- Real-time systems that replicate data across
- Peer-to-peer network topology
- Usage of cryptography and digital signatures for identity, authenticity and enforce read/write access rights
- Mechanisms that make it difficult to change older records, and make any attempts to do so easily detectable

In order to be part of a blockchain a user needs to install special software that connects them to other participants on the network. When you run the software you become a node in the network and you act like an individual validator. Once connected to the network for the first time a node will download the entire copy of the blockchain database on their computer. (Fig 25)

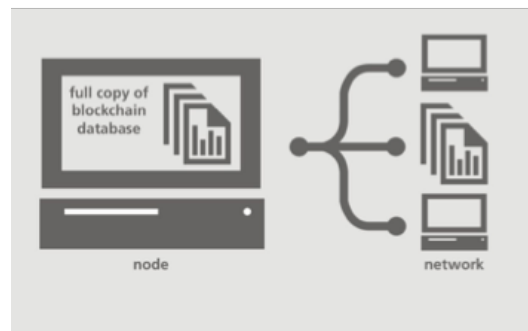


Fig 25. Blockchain Node

The database is going to be managed by the nodes that connected as per the existing protocol. Each node becomes an entry point that can add new data to the network as well as validate and propagate other new data. (Fig 26)

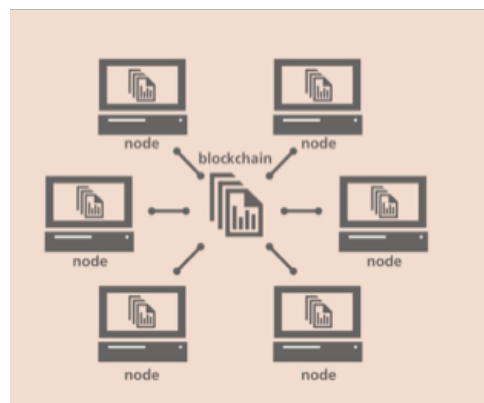


Fig 26. Blockchain Nodes

In order for a distributed system, like the Blockchain, with no golden source of truth to reach consensus and agree to what data to write on the blockchain, which is similar to the situation where equivalent people can say conflicting things and there is no higher authority to arbitrate, we must rely on protocols. The blockchain protocols will assure technical and business validity of the data being written and determine how consensus is achieved.



Fig 27. Blockchain protocol

The block is the basic unit used to stored data on the blockchain, blocks are created by grouping together similar transactions. After a block is created it is added in chronological order, thus resembling a chain, this is the reason why we name the technology blockchain. The nodes on the network will then store the new blocks on the local blockchain on their computer.

**Blockchain Used in Decision making**

Even though, so far, most of the use cases for blockchain involved crypto currencies we can extend the way we use it in fields where it can have an even greater impact, like decision making and social governance. The distributed and decentralized database that the blockchain provides has 2 properties that makes it a perfect candidate to be at the base of a trust-less collaborative decision making environment:

- 1) Transparency - because data is shared between all the nodes of the network, which in the case of a decision making environment would translate to deciding agents, everyone will have access to the whole history of transactions or decisions that were taken until any given point, this means that any new decisions or transactions will automatically take into account previous decisions.

2) Incorruptibility - data stored on the blockchain cannot be altered because locally altering any unit of information on any given block would create an inconsistency between the altered blockchain and all other nodes on the network.

These two properties are crucial for creating a trustless decision making environment where each agent in the decision making process doesn't need to rely on the trustworthiness or good faith of the other agents. Because all information relevant to the decision making process is distributed between all deciding parties and all previous decisions can't be corrupted or overturned by any of the participating member, each new decision that's being taken will be based only on real and relevant information. This will ensure that for every new decision making iteration the issue being decided on will be better understood and addressed.

# 4. Environment Architecture and Decision Blockchain

The designed architecture (Fig 28), modeling the identified internal organic operating system components of the human body, that uses blockchain technology and micro-services, around which the Integrated Decision Making Environment is being build.

One of the main components of the Integrated Decision Making Environment is the ranked social network or Trust Rank Component. The ranked social network will allow individuals that want to get involved to receive direct votes of trust from other users with the scope of creating an organic and dynamic hierarchy, which will later be used as main metric to fill specific roles in the organization using the platform (Department, Institution, Corporation, State, etc.).

The three classical branches of power in decision making: Legislative (left brain hemisphere), Executive (spinal cord) and Judicial (right brain hemisphere) [9], are formed from the individuals located at the top of the trust hierarchy which are interested in taking part in the decision process and posses the capabilities needed for the available roles of each branch.

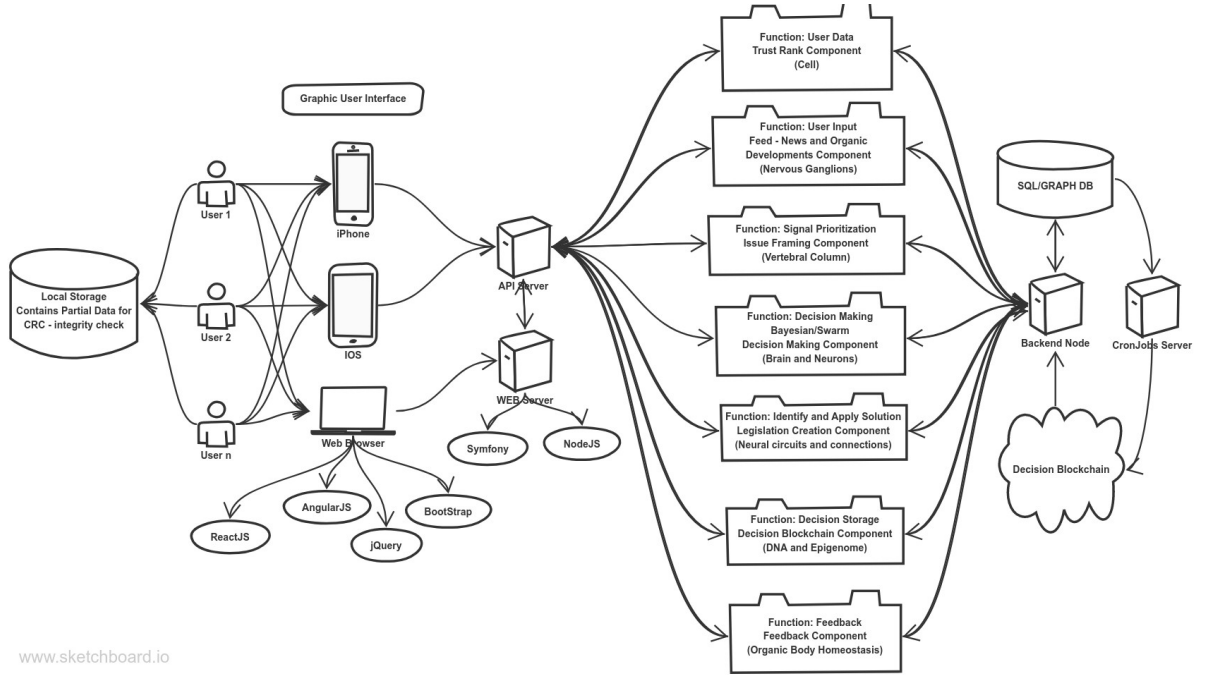


Fig 28. Architecture of a generic Decision Making Environment Server Infrastructure

The frontend components of the Integrated Decision Making Platform that use the Decision Blockchain as data source are: *Trust Rank Component, Legislation Creation Component, Feed*

*- News and Organic Developments Component, Issue Framing Component, Feedback Component, Bayesian Decision Making and Swarm Decision Making Component and of course the Decision Blockchain.*

Trust Rank Component will have the function of identifying each user and creating an organic hierarchy of the users taking part in the decision making process and it will look like a Ranked Social Network. Personal information will be attached to each user saved on the blockchain as well as their Trust Rank which will be obtained from direct Votes of Trust.

Feed - News and Organic Developments Component have the function of gathering information from the users, which make up the governed body, so that issues can be identifying and prioritized so that they can be solved. Users can post news relevant to the society they form and Organic Developments that reflect everyday problems or general observations. This component does the job of nervous ganglions that gather and priorities signals received from individual cells and organs to be forwarded to the brain if critical.

Issue Framing Component has the role of framing specific issues from the data collected by the Feed News and Organic Developments Component. This will be equivalent of the function of the vertebral column that sends signals from individual cells and organs to the brain. So the more critical a Issue is the faster it will reach those in the position to find solutions and take action.

Legislation Creation Component has the role of identifying and storing the solutions found for each issue in a very granular way so that further changes and optimizations can be made along the road very easily. The Legislation Creation Component allows us to represent complex solutions, like rules, laws or regulations into multiple Law Atoms, which are small logical statements that include objects and variables previously described, and store them to the Decision Blockchain for dissemination throughout the governed body.

Bayesian Decision Making and Swarm Decision Making Component are the two components that complement each other when it comes to making decisions. These two components emulate the function of the brain and neurons and allows individual users that take part in the decision making process to collaborate similarly to how the human brain does when making decisions. The Bayesian Decision Making Component offers a more complex interface and it allows for solutions to be found when dealing with quantifiable information that can be put into variables, or in this case belief factors for the Bayesian network. Each user will have the possibility to put in their own factors of belief and the Bayesian statistics formulas will allow us to calculate a

collective value for each solution, taking into consideration everyone's trust rank and belief factors.

The simpler Swarm Decision Making Component allows for fast solutions to be found when dealing with subjective beliefs by simulating a swarm like environment using an intuitive interface provided by the UNU [11].

Decision Blockchain Component handles communication and synchronization with the Decision Blockchain. This component will handle data synchronization and user authentication so they can use the Decision Blockchain. This component is the equivalent of a body's DNA.

The Feedback Component has the role of maintaining homeostasis inside the governed body, it takes feedback from the users (individual cells), and attaches it to each decision that was stored on the Decision Blockchain.

A more detailed description of each component is given in Chapter 5.

The components work together to form an intuitive interface to the Decision Blockchain. In order to create the interface and component interaction we studied and emulated the way signals are collected and processed inside the human central nervous system.

The architecture (Fig 29) of the Integrated Decision Making Environment is based on micro-services built around a distributable data model using blockchain technology, connected using Symfony social network framework or custom built user interface and backend using AngularJS/React/Redux framework, in the form of independent widgets, complemented by a REST API framework and a Graph database for long term storage and fast queries and MySQL for common operations.

The technologies for the frontend and middleware that interface the decision blockchain are:

Symfony – php framework and reusable components

Flight PHP - fast, simple, and extensible framework created for easily building RESTful web applications

Sparrow – PHP DB toolkit PHP that can link together multiple DBs.

MySQL – common operations DB

OrientDB – graphDB used for long term data storage

Bootstrap – Javascript framework used for Widget creation

Jquery – Javascript framework used for HTML DOM manipulation

React – Javascript framework for modular widget template creation and data binding

AngularJS - Alternative javascript framework for widget creation and data binding.

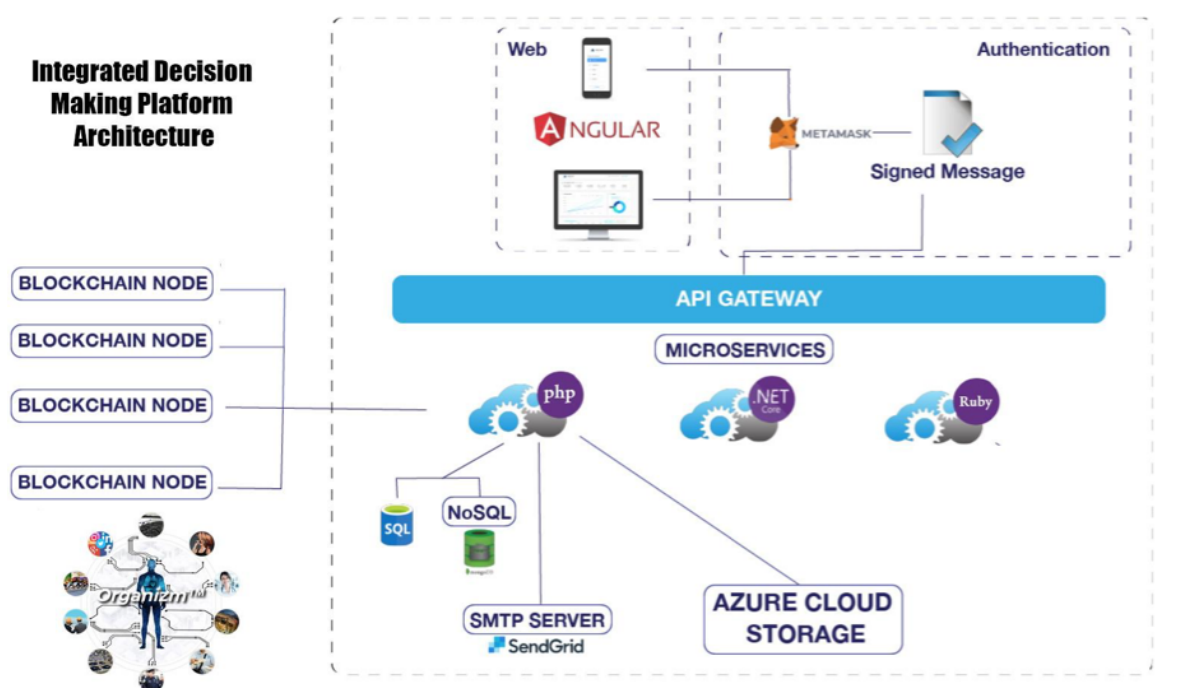


Fig 29. Integrated Decision Making Software Architecture

One of the main components of the Integrated Decision Making Environment is the ranked social network. The ranked social network will allow individuals that want to get involved to receive direct votes of trust from other users with the scope of creating an organic and dynamic hierarchy, which will later be used as main metric to fill specific roles in the organization using the platform (Department, Institution, Corporation, State, etc).

The three classical branches of power in decision making: Legislative (left brain hemisphere), Executive (spinal cord) and Judicial (right brain hemisphere), are formed from the individuals located at the top of the trust hierarchy which are interested in taking part in the decision process and possess the capabilities needed for the available roles of each branch.

The Integrated Decision Making Environment can be used to model all previous modes of government like Democracy, Monarchy, Communism, Republic by allowing citizens to dynamically and collaboratively create and modify the constitution and the laws/rules of the institution, department, organization, state, etc, and the governing roles that will be assigned to the most trusted citizens.



Another important element of the Integrated Decision Making Environment is the nervous ganglion algorithm used for filtering, prioritizing and routing the messages, ideas, issues coming from the individuals that constitute the governed body. The algorithm (Fig 30) uses the already functioning popularity algorithm from Reddit with the specification that each user has the voting power increased depending on his number of votes of trust (position in the trust hierarchy).

```
function hot($ups, $downs, $date)
{
    if (is_string($date)) $date = strtotime($date);

    $s = $ups - $downs;
    $order = log10(max(abs($s), 1));

    if ($s > 0)
        $sign = 1;
    elseif ($s < 0)
        $sign = -1;
    else
        $sign = 0;

    $seconds = $date - 1134028003;

    return round($sign * $order + $seconds / 45000, 7);
}
```

Fig 30. Post priority function

The Hot Function (Fig 31) sorts the posted Issues, Organic Developments, News, by the time of submission (newer items are higher) with the specification that for each Up-vote the item moves forward in time, becoming newer, while Down-votes push the item back in time, making the items appear older, thus showing lower on the list.

```
function confidence($ups, $downs)
{
    $n = $ups + $downs;

    if ($n == 0) return 0;

    $z = 1.281551565545; // 80% confidence
    $phat = $ups / $n;

    $left = $phat + 1/(2*$n)*$z*$z;
    $right = $z*sqrt($phat*(1-$phat)/$n + $z*$z/(4*$n*$n));
    $under = 1+1/$n*$z*$z;

    return ($left - $right) / $under;
}
```

Fig 31. Confidence function

The Confidence function is used to sort the comment list based on user votes. Comments are used by users to intervene with relevant ideas in all steps of the decision-making process, from Issue framing, to Policy Creation, to execution and even judicial (solving disputes).

As an example for Hot Algorithm, if  $n = 10$ , then  $\log(10) = 1$  and the post is moved forward 45000 seconds, or 12.5 hours. If  $n = 100$ , then  $\log(100) = 2$  and the post is moved 90000 seconds, or 25 hours. We can plot (Fig 32) this for more and more net up-votes:

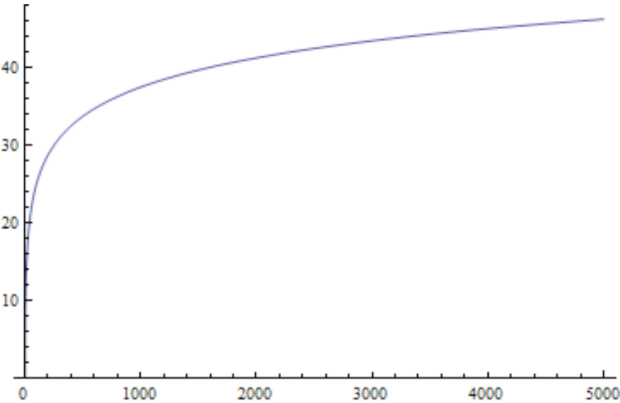


Fig 32. Hours added as a function of net up-votes received

### 4.1 Decision Making Components derived from the human anatomy

Most of the components we're building are inspired by the biological governance model of the human body. We create a game model that uses a player(actor) or cell or neuron, a network for information distribution, the internet, and a processing unit that takes care of all possible player to player and player to network interactions using blockchain technology so that we form organic swarms similar to human nervous ganglions.

In anatomy, a ganglion is a nerve cell cluster or a group of nerve cell bodies located in the autonomic nervous system. Cells found in a ganglion are called ganglion cells, though this term is also sometimes used to refer specifically to retinal ganglion cells.

Ganglions are customizable based on the environment they are deployed to serve in, these ganglion systems are going to be represented by individual processing components used by the platform.

Ganglions can be alternatively seen as organizational groups similar to political parties or bee swarms.

Users can configure their ganglion based on questions that address key cell needs and wants in a physical wise way, storing the answers as a template for later use as a constitution of the ganglion.

We can make suggestions for cells to join ganglions based on short surveys addressing main psychological, cultural, ethical topics.

Each new cell that joins a ganglion provides extra credentials and decision power for that ganglion.

The ganglion ranking system will be based on followers and members. You can be member of one ganglion and show support or follow another. Ganglions can also vote for other representative ganglions in matters outside their interests or knowledge.

The voting power of a ganglion is given by the number of supporters and number of members.

The individual cell vote can be passed on to another cell as a representative, when that happens if your representative joins a ganglion he will also branch you to it and use your voting power as his own inside the ganglion.

The decision power of a ganglion will be given mainly by the quality of it's output to issues relevant to the body or society, we consider quality as being directly proportional with the number of members and followers.

Ultimately the responsibility of the way the system works lies on the individual cell.

The cell configuration protocol will use surveys to match the new cell to other matching cells.

If some cell falls outside the existing ganglions based on its answers a new ganglion will be built around him and activities for his party can be chosen from the pre-existing pool or new ones can be created if they generate interest or are voted as popular.

The platform has the same properties of water, being totally transparent and taking the shape of the container it is put it, the container being the totality of individual cells with all their specifications.

### **Organic decision making fractal**

The human central nervous system is the unfolding of a fractal which sole purpose is to coordinate the activity of the human body and connect more than 38 trillion cells into one coherent organism. Because of its fractal nature, the central nervous system manifests self similarity, and because we have an idea about how the macroscopic mechanisms that make up

the central nervous system work, we can infer that at a microscopic level the general functions are preserved but expressed in different forms. The division of the brain in two hemispheres united by the corpus callosum can also be found in a different form in the nervous ganglion.

Also the functional division of the central nervous system in autonomic (sympathetic and parasympathetic) and somatic is also proof of the underlying motif used by nature to divide and conquer.

The functions and structure of the central nervous system encodes the best interface and functionality that implemented into an actual platform, using modern technology, would enhance and mitigate the act of decision making for any group of individuals regardless of the issues being decided upon.

Global peace and coherence can be attained when the core beliefs that are identified match the requirements of all human beings on the planet, for instance when we all decide that equality, freedom, water, clean air and education are universal necessities, the main core, universal normative, of the human species will be created and, just like the self similarity of a fractal, applied into all organizations formed by humans (countries, corporations, religions, etc) and from the core rules each organization can derive their own custom rule sets, in the form of constitutions or doctrines, that identify them as separate entities and provide a unique culture and traditions. With these core values identified and implemented into each decision making structure (countries, institutions, corporations, personal, etc) using the decision making environment we are proposing, the human species can start acting like one body.

### **Decision Making Roles inspired by the Human Body Anatomy**

The human brain is split into 2 hemispheres and united at the centre through the corpus callosum that connects the spinal nerve that is the main agent that allows our limbs and organs to be coordinated with each other for the good of the body as a single coherent unit. From this we can determine that there are 3 main roles that assures the good functionality of the body, the left hemisphere, the corpus callosum, and the right hemisphere. Medical research has shown that the right and left brain hemisphere have different, complementary roles when it comes to functionality. And the corpus callosum has the role of uniting and mediating between the two hemispheres and the rest of the body. [4] [1]

We can see these 3 roles in the way modern governance systems are split in the executive branch, legislative branch and judicial branch. Even without realising it we were inspired from

the way nature unfolds itself through each biological form it takes and the anatomical structures it creates to coordinate and govern itself. Thus, when creating a governance system that is to be aligned with the way our anatomy is built we must integrate this 3 way division as a fundamental feature of its architecture.

For this we must first identify each of the three roles in concordance with the medical studies done so far.

The right brain hemisphere is responsible for control of the left side of the body, and is the more artistic and creative side of the brain. The left brain hemisphere is responsible for control of the right side of the body, and is the more academic and logical side of the brain.

The corpus callosum is a thick band of nerve fibers that divides the cerebral cortex lobes into left and right hemispheres. It connects the left and right sides of the brain allowing for communication between both hemispheres. As we noted before we already have a 3 branch governance system in place. The right hemisphere which is responsible for spatial awareness, creativity, movement, represents the executive branch. Because the executive branch is the one that actually puts in action the laws the legislative branch creates, the most important aspect when considering the individuals that will make up this branch is their trustworthiness. For this we must consider a way to quantify trust and create hierarchies from the individuals interested in taking part in the executive branch, or right side of the brain. If an individual has a lot of skills but can't be trusted he must definitely not be allowed to act on the governed body. [25]

The left brain hemisphere, or legislative branch is inclined towards mathematical, logical and academic reasoning. Because legislation does not have direct effects we shouldn't be concerned with trust, the opposite should apply here, the less people that work on the legislation trust each other, the better the laws will be and will stand up to scrutiny and exploitation. In the legislative department we don't want people driven by trust but by logic, reasoning and mathematics. For this we must consider a way to quantify reasoning, wisdom and logic that will be included in the governance platform to create an accurate hierarchy of the people involved in the process of decision making and governance. Because we don't want evil geniuses colluding with each other to take over the body we must assure they are snakes (that's why the snake is the symbol for wisdom). Snakes live solitary lives, act alone and they eat each other when hungry without considering any affiliation of race, gender or sex. In order for these 2 branches to work together properly we need to implement a mediator structure, that represents the corpus callosum, that

will act on the bodies behalf and will have power over both right and left hemisphere. In the current governance systems this is represented by the Judicial branch.

The individuals that are part of the judicial branch, or the corpus callosum aren't part of the decision making process but instead they mediate between the body, civil society that doesn't get involved in the governance of the body, and the two branches of governance, legislative and executive. The people involved in the judicial system have to be both wise and trustworthy.

Creating the right environment and interface for the people that completely lack trustworthiness to be in charge of legislature would be ideal because the laws that they create provide the means for people like themselves to cohabitate without conflict. Thus, the same people for which the laws are needed, are the best people to actually conceive the laws. So the platform will act as a mediator for people that are focused only on their own self interest to protect themselves from people of the same nature.

As an analogy, hackers should know the best methods to protect themselves from other hackers. But in order for them to come together to actually create such legislation, the platform or mediator that is used needs to be completely transparent, decentralized and neutral so it can be trusted. Neutrality is an intrinsic property of nature, nature treats both honest and dishonest people equally, because both are allowed to live and are given the needed tools to survive and evolve. So a platform that is inspired by nature like the one in discussion should create a favourable environment for both dishonest people and honest people to thrive. The correct way of living shouldn't be something imposed by the governance system but should be obvious to each individual that observes the traits that are encouraged through the process of evolution. And I'm not talking about physical evolution but the evolution of consciousness that's a result of education, because we can see that different people create different societies, some more civil others more chaotic and barbaric depending on how much they emphasize the correct human values through education. Not all things are of equal value and not all people are the same, that's why when it comes to setting up standards we must take into consideration the fact that not long ago most people would behave in ways that are unacceptable in today's society and nothing was ever learned by force. If a personal change doesn't come as a self realization that change will not last. So the best thing we could do for the humans as a species and as individuals is to provide a flexible environment that will accommodate all individuals regardless of how they position themselves relative to the correct human values. In this regard, through the platform I am describing, people that share same beliefs can associate and live out

their own version of truth and value and through personal experience eventually evolve to discover the true human values.

## **4.2 Holistic Decision Making**

The classical model of decision making is based on the assumptions that the deciding agents have access to complete information and are capable of making the optimum decision by weighting every alternative. Needless to say that this is never the case because such a capability can never be provided by systems that don't have a holistic view over the object upon which the decisions are applied and such unknown variables will hinder performance, profit or overall satisfaction. [26]

The Integrated Decision Making Environment provides the means by which we can migrate from the classical 'blind' decision making model to a holistic model for decision making and management.

In Holistic decision making we are encouraged to be aware of our actions and impact they have on the whole. It creates an environment in which people take responsibility and accept being held accountable for their decisions. This empowers the deciding agents to be part of an ongoing process of change. Using a holistic approach allows for a number of different factors to be taken into account.

The Integrated Decision Making Environment, based on it's holistic approach, enables participants to make decisions based on their deeper values, which will be economically, socially and environmentally sound.

Holistic Management instead of seeing different parts as being separate will address all the parts as an integrated whole. Holistic management creates a new framework for decision making that is based on resource management of the whole on all its levels.

Using the Holistic Management methods, we can identify all the people that are important and the resources related to the issue that's being solved and bring them together as one whole with the help of a statement of purpose. With the broad holistic goal defined by the statement of purpose, the group that is formed has a benchmark using which they can quantify the quality and efficiency of their decisions. A subsequent feedback phase reaches back to often ignored considerations to make sure that none are being forgotten, for this we will use the Feedback Component, based on the felicific calculus formula, that assesses the overall satisfaction for

any given decision that was taken and begins another iteration of the decision process if needed.  
[26]

### **Upgrading the three branched governance structure**

It is said that power corrupts and absolute power absolutely corrupts and because of this human governance has migrated from a single all powerful ruler, dictator or king, to a more decentralized governance structure where the parts composing the government keep themselves in check by splitting the authority of the governance process between them. The most well known model for decentralized governance is the three branched governance structure. The three branch governance structure is also aligning with the anatomy of the human central nervous system, our brain being divided in two hemispheres which are split and at the same time connected by the corpus callosum. Each of the three branches have a very well defined function in the governance and decision making process and at the same time there are mechanisms in place that assure none of the three branches gains excessive power over the other two. Even though the idea behind the three branched government is a sane one and align with natural patterns of decision making, the human factor again causes problems in the form of corruption. Corruption is mainly possible because of the lack of transparency inside the current governance process, each institution keeps their records private, laws aren't easily accessible to everyone, the governed body doesn't have any interface that allows it to interact with the deciding agents, resource management and budgeting is also controlled by a small number of individuals and resource distribution is most of the time biased and in conformity with a few individual agendas. In order to address these problems, we look at nature for answers and as sure as the sun will rise nature provides us the solutions to our problems in more ways than one. At the base of the Integrated Decision Making Environment are a number of natural patterns that the fractal of life uses in places where governance and group decision making is needed like: - the bee swarm, where we can understand the mechanisms of swarm/collaborative decision making as well as methods to integrated distributed knowledge and converge on a final - brain neurons, which make decisions in a similar way with a bee swarm, they inhibit and excite each other to form networks which represent abstract solutions to the problems we are looking for. When the brain makes decisions it doesn't rely on all the neurons, or even the majority of neurons, to converge in a network. Instead a decision is made when only a certain threshold is reached which represents only a sufficient quorum of excitation - from the human DNA code we gained the knowledge of creating the blockchain,



which is a distributed database that allows for the information inside the system to be available to all deciding agents and governed body without actually being centralized and vulnerable to unauthorized changes by the authority in charge of it - the three parts of the brain provided us with the pattern that we used to create the three branched governance system, which was also adopted by the Decision Making Environment - the central nervous system inspired the interface needed for the deciding agents to interact with the govern body as well as the creation of the feedback loop functionality in the form of the Feedback component that uses the felicific formula to assure overall satisfaction for each decision being taken.

**Convergent or Divergent Decision Making and Governance**

The Integrated Decision Making Environment flexibility allows us to configure it to match any existing government system. The main decision that needs to be made though is regarding the distribution of responsibility over the whole governed body, which can converge to one person (Fig 33), which can be called a president, rector, CEO, etc, or can diverge so that the responsibility of the whole governed body will be divided between each deciding agent, it's subdivision and ultimately the members that are part of it.

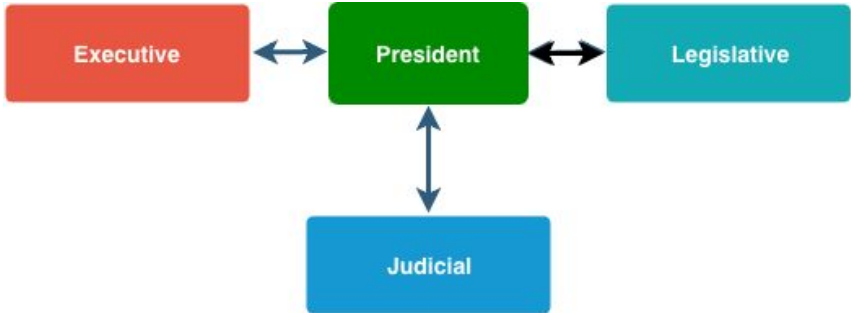


Fig 33. Classic convergent three branched governance structure

The classic convergent three branched governance structure places the President as the mediator between the three branches and the governed body. The role of the president is to represent the governed body in front of the three branches and provide a identity for the whole. Because the president of a democratic system doesn't have absolute power over what happens inside a state he also has limited liability, because the responsibility is also distributed among the deciding agents that make constitute the three branches of government, Executive, Legislative and Judicial. The advantages of using a convergent system of governance is that the governed body is actually presented by a single individual that has to take responsibility thus ensuring, at least in theory, a less favourable environment for corruption. Obviously this doesn't happen in real

life but using the Integrated Decision Making Environment we can incrementally perfect this structure to completely remove the possibility of corruption within the governance structures.

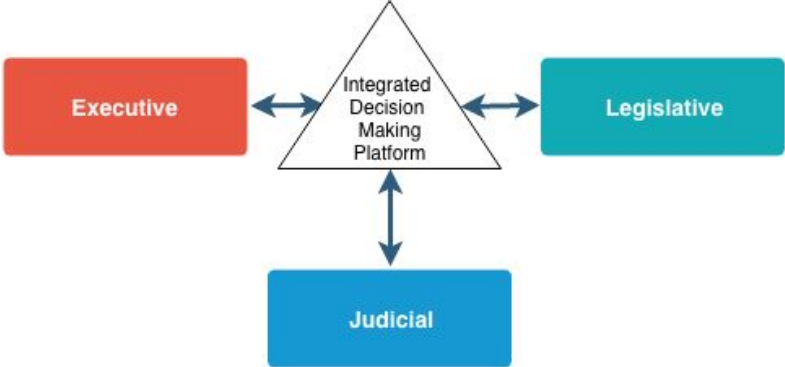


Fig 34. Divergent Three branched governance structure using the Integrated Decision Making

A divergent three branched governance system (Fig 34) can be possible by completely removing the president and replacing him with a collaborative interface that acts as mediator and feedback loop that would allow the governed body to assess the decision making process of the decision making institutions and the agents that constitute it, provide feedback, request and support changes by direct votes and the issue framing and management component. The disadvantage of a divergent system is that the whole governed body can suffer an identity crisis in the form of schizophrenia subdivisions that have completely different views from the rest of the governed body. Also a divergent system would require increased effort coming from the governed body because ultimately they are the one responsible for not properly interacting and guiding the three branches of governance.

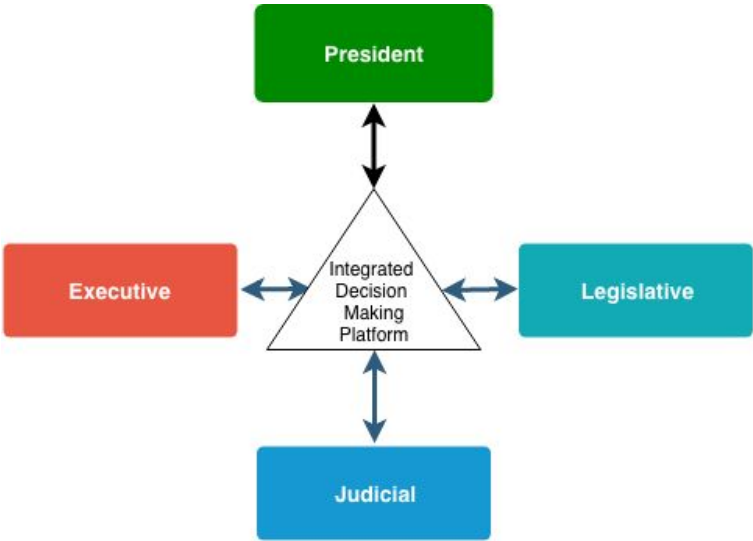


Fig 35. Convergent three branched governance structure using the Integrated Decision Making

The best solution (Fig 35) would be a convergent three branched governance system where the president will be the person with the most votes of trust and the president role would require the person in that role to take full responsibility for the overall governed body and mitigate any possible conflicts between the three branches of governance and the governed body. Another advantage would be that the identity of any institution adopting this structure will be very well defined and the values and goals of the person taking the president position would be a reflection of the whole governed body, thus offering a mirror in which the system as a whole can reflect in and if needed adopt pertinent changes.

### **4.3 Decision Blockchain**

Blockchain technology was first used in crypto-currency systems to keep a ledger for transaction. Each transaction was saved in a list and when the list arrived at a certain size a new list was created and the old list would be hashed, and the hash code to the old list would become the starting value of the new list so each block(list) would be chained and validate each other.

This way if a change would have been done to an older list, let's say something would add a fake transaction so it would seem their account has more resources than it actually has, the hash of the resulting list would be different than the next list after it. So if you would actually want to add a transaction you would have to go through all old lists that were already processed and calculate a new hash for each of them. And that would be from a processing point of view almost impossible because the blockchain is distributed and the one doing the change would need more processing power than all the other nodes that keep a copy of the list put together.

A system of this sort should be used in the way we keep track of each decision we do as individuals and as a society. This way we will keep a track record of all decisions made that would be impossible to counterfeit from which we could extract and learn using Artificial Intelligence software the best course of action for each issue in such a way that new decisions would have the support of the best suggestions extracted from past data. This can be applied to each individual but also to the governance structures we use in society in any form of organization, like education, transport, health, environment, economy, etc.

The blockchain (Fig 36) is a way of storing data that creates a distributed and decentralized database which ensures data consistency through cryptography. Blockchain technology became popular because of the Bitcoin crypto currency. Crypto currency is a form of digital currency

that uses the blockchain as a ledger for financial transactions, which also provides transparency because of its distributed and decentralized nature, and cryptography as a means of protection against double spending.



Fig 36. Simple Blockchain structure

**The Governed Body**

The governed body is made of the individuals that are affected by the decisions being made using the Integrated Decision Making Environment that’s using the Decision Blockchain, which consists of **Deciding Agents** and **Unqualified Users**. Deciding Agents are individuals that have the right to submit decisions or vote on them according to the existing legislation stored on the blockchain.

Unqualified Users are either individuals that don’t yet meet all the requirements to become Deciding Agents (because they are too young) or people that lost the privilege temporarily or permanently based on past behavior. Even though you are an Unqualified User you can still contribute to public debates and receive public acknowledgement through other types of votes, like vote of wisdom, and doing so indirectly influence the decisions being made.

**Body of Governance**

The body of governance consists of Deciding Agents that are implicated in the decision making process and have specific roles that serve the governed body, or it’s organizations and institutions, in the legislative, judicial or executive branch.

**Decision Blockchain as Artificial DNA**

The Decision Blockchain can be seen as the artificially created DNA (Fig 37) of any Body of Governance, where each individual is the equivalent of a cell and each cell contains a full copy of the whole blockchain just like biological cells contain a full copy of the DNA. Each fork created in the decision blockchain with the purpose of defining a new institution with its own internal rules and role is equivalent to the different organs of the human body that have

specialized functions useful for the whole body, thus creating a virtual delimitation between the new institution (organ) and the rest of the body. The Deciding Agents have roles that are equivalent to the different cell types the human body, each with their own well defined purpose depending in what Institutions or Organizations they activate.

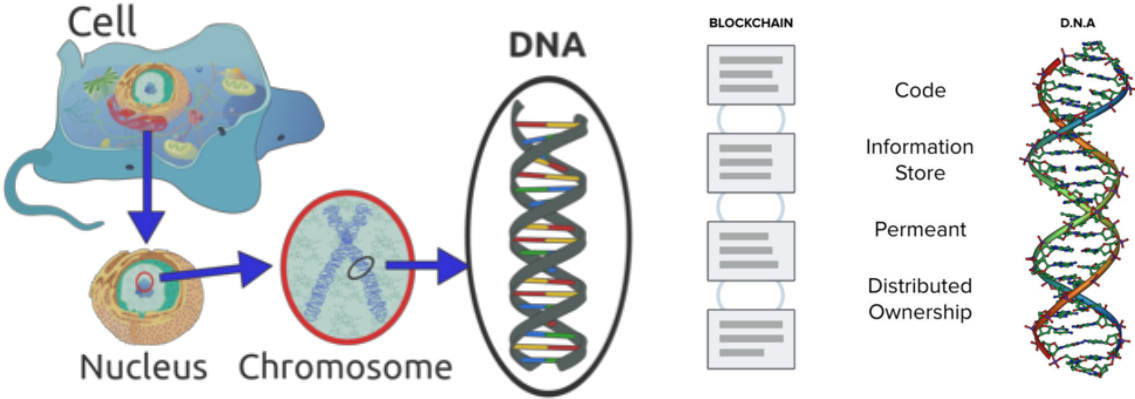


Fig 37. DNA resembling the Blockchain decentralized Database

The similarity between the DNA and the Blockchain has important implications in the way we can debug the decision making process similar to how geneticists use DNA sequencing to trace back certain traits, properties or behaviors in different organisms to their genetic triggers. This can be done by using the structured data found in the blockchain which can be defined at a very low level of granularity and linking it to the observed effects it has on the governed body, which with the help of the feedback component are also going to be stored in the blockchain. Having created a strong link between causes and effects the deciding agents will be able to fine tune the decision making process and laws that govern the body so that with each iteration the body achieves a greater level of coherence and heterogeneity. It is known that biological organisms evolve as a response to external factors and this property will also emerge and manifest itself inside any collective using the integrated decision making environment.

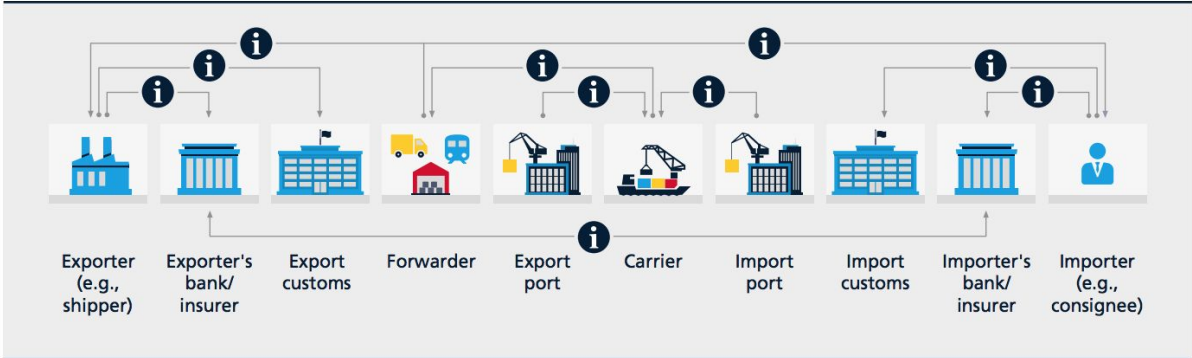


Fig 38. The information flow in international trade is complex, involves many parties, and is documentation heavy

Using the Decision Blockchain we enable data transparency and access among relevant supply chain entities, creating a single source of truth.

Intrinsic security mechanisms of the blockchain technology will enhance the trust between stakeholders to share information (Fig 39). Cost saving can be achieved by powering leaner, more automated, and error-free processes. On top of adding visibility and predictability to logistics operations, it can accelerate the physical flow of goods. Provenance tracking of goods can enable responsible and sustainable supply chains at scale and help tackle product counterfeiting.

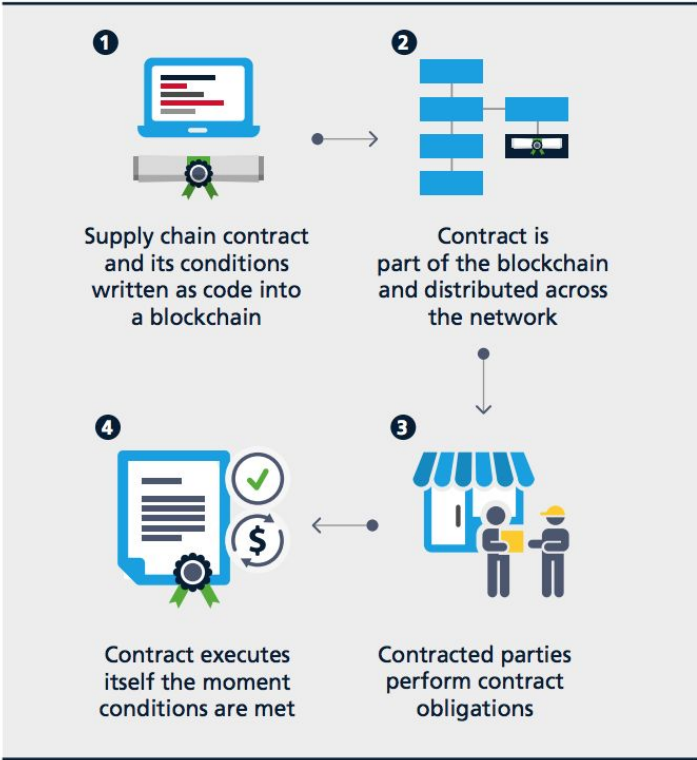


Fig 39. How smart contracts could work in the logistics industry

### Decision Block Structure

The fundamental type of block in a decision blockchain is the **Decision Block**. On top of the Decision Block, which is the primitive block type, we can have additional block types that will have their properties defined by the deciding agents through the fundamental Decision Blocks. The Decision Block will specify the object applying a certain decision and the object that can be affected by a decision. The objects used in decision blocks will be described in special blocks derived from the basic decision block and should be previously added to the blockchain. The decision block (Fig 40) will specify the object(s) applying a certain decision

and the object(s) that can be affected by a decision as well as the logic that connects and describes the interaction between the two objects.

Using different block types will allow us to fork and create different institutions, organizations, layers of governance, deciding agent hierarchies based on different types of votes (trust/wisdom) and also create context dependent systems of governance that only affect a certain branch of the blockchain and the deciding agents involved in it. Each of these sub chains will be created with a specific purpose in mind and annexed to a previous decision block.

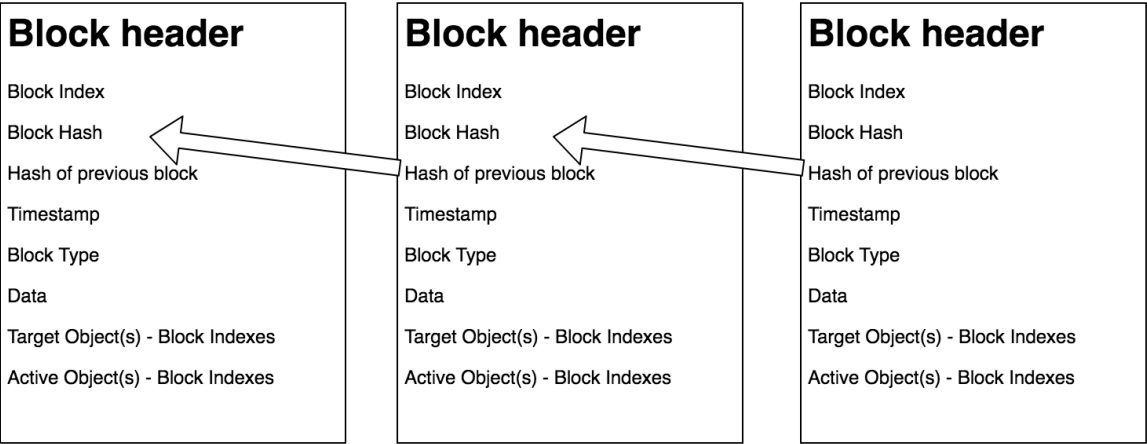


Fig 40. Basic Decision Block used in a Decision Blockchain

Through decision blocks we will store the normative, principles, constitution, legislation and deciding agent roles of the governed body and the organizations and institutions that evolve inside of it.

In order to accurately model how decisions are made in real life we will need a few more block types:

- 1) **Definition Block** - will be defined using a primitive decision block but with the added type member specific to a decision block. A definition block will contain the description of a concrete or abstract object. The purpose of the definition block is to be used as a reference in other decision blocks. For instance: definition for energy, definition for human, definition for president, etc. The Definition Block can have global effect or contextual effect.
- 2) **Action Blocks** - will define an action that an object, defined in a Definition Block (example: Institution), can exert on another object, Resource, Deciding Agent or Unqualified User.

- 3) **Resource Block** - will record the stock or supply of valuables such as money, materials, staff, and other assets that can be drawn on by a person or organization in order to function effectively. The Resource Block will also keep track of resource usage by recording negative values after they are allocated. The Resources can be administered, regulated and supervised by a special organization established through the decision blockchain.
- 4) **Deciding Agent Block** - this will store personal information pertaining to a deciding agent like: public key, name, strengths, weaknesses, skills, etc. Each new Deciding Agent Block will be introduced in the blockchain only after being validated through votes by existing deciding agents depending on the existing legislation introduced in the blockchain at any given time.
- 5) **Vote Block** - will store a vote made by a deciding agent and it can have different subtypes:
  - a) **Vote of Trust Block** - this block will be linked to an existing Deciding Agent and can only be given by another existing Deciding Agent. Each Deciding Agent can only give one vote of trust. The minimum period of time that a vote a trust will be valid will be defined through a Decision Block. Once a vote a trust is given the Deciding Agent receiving the vote will carry the authority and responsibility of the Deciding Agent from which he received the vote.
  - b) **Vote of Validation Block** - this block will be linked to a Decision Block and based on the existing legislation, which can be found on the blockchain, it will be needed to validate a certain Decision Block. When a new decision is made, using an independent interface that extracts data from the blockchain, the Deciding Agents that are needed for a vote to be validated will need to use their private keys to create a Validation Vote for the decision being added, if the Validation Votes don't reach the needed critical mass (calculated in total votes of trust), in accordance to the existing legislation, the Decision Block and Votes of Validation Blocks will be discarded and not added to the blockchain. In order for a Validation Vote to be Submitted the Deciding Agent also has to provide a short logical explanation for the reason they are validating the vote. This way we make sure the Deciding Agents understand the reason for their vote.



- c) **Vote of Invalidation Block** - this is an optional block type and it will be linked to a Vote of Validation Block. If the voting reason attached to a Vote of Validation is too weak or irrational it can be challenged by other Deciding Agents and if it received enough support from other Deciding Agents it will invalidate the Validation Vote it targeted. The quantity of Votes of Trust needed to invalidate a Validation Vote will have to be decided previously on the decision blockchain and it will be relative to the number of votes of trust attached to a Vote of Validation Block.
- d) **Vote of Wisdom Block** - this is a optional block type that targets a Deciding Agent. This type of block allows for Deciding Agents or Unqualified Users to be rewarded for insightful input on the independent online platform user interface that uses the decision blockchain and will automatically expire after a certain period of time in conformity with the existing legislation. The purpose of this type of vote is to provide extra exposure on the platform's online user interface for people that don't want to be directly involved in the decision making process but are qualified and capable of providing valuable insight, feedback or solutions.

6) **Feedback Block** - this type of block can be added by any Deciding Agent or Unqualified User and it targets a Decision Block. The Feedback Block will store a simple feedback or an expanded feedback and it will be added using the Feedback Component.

The information stored in the blockchain as a decision block would be immutable because new decisions would only be stored as new blocks and would require the confirmation of the nodes with the highest trust ranking.

When new decision blocks are added they are only validated if they are signed using the private keys of the nodes with the highest trust ranking depending on the amount of votes of trust relative to the total population which should be previously decided in the legislation in the form of decision blocks. The nodes with the highest trust ranking are Deciding Agents that receive votes of trust from the other participants in the decision making process.

Based on the votes of trust we can create an organic hierarchy that will aid us in identifying the most trustworthy people for roles that affect a largest segment of the governed body.

The JSON object that specifies the settings and properties of the blockchain has the following structure:

```
blockchain_component_config{  
    multichain: true/false, // flag for setting multichain support  
    allow_founder_role: true/false, // flag for setting the existence of admin role that has infinite vote of trust  
    enable_resource_blocks: true/false, // flag to enable or disabled resource management support using the blockchain  
    complex_voting: true/false, // enable complex voting support  
}
```

### **Decision Blockchain Configuration Protocol**

The Integrated Decision Making Environment components have been designed based on the human anatomy and various naturally occurring phenomena and processes like swarming and the human neural decision making process. The human body configures itself based on personal experience and adjusts its reaction to the outside world after each decision you make, storing what it learns using the epigenome, which is involved in regulating gene expression and development. Unlike the underlying genome which is largely static within an individual, the epigenome can be dynamically altered by environmental conditions.

Based on the epigenome we designed the configuration module to provide similar functionality by gathering relevant information about the governed body and the external environment the body is suppose to function in and at the same time provide the necessary flexibility for the platform to adapt and evolve while being used. More specifically we identify the purpose or the intention of the governed body (why?), the methods and capabilities which are going to be used to implement the purpose (how?), and the products or services that will be delivered as the fulfilment of purpose.

Based on these initial settings we can enable or disable parts of the Integrated Decision Making Environment, which represents the DNA (static genetic code / genome), to provide the best results both in user satisfaction and in fulfilment of purpose. In order to create an intuitive configuration interface and identify relevant connections between the purpose and the needed

capabilities of the platform, we will systematically describe the components that constitute the Integrated Decision Making Environment and the scenarios in which it makes sense for them to be used and from these we will describe the Epigenome equivalent, which will be a JSON config object stored on the blockchain that will enable/disable each feature of the platform.

#### 4.4 MultiChain Resource Management

Based on the Decision Blockchain we will create a resource management and logistics component where resources are controlled by owners (which can be individuals, institutions or organizations) and the right to access or distribute each resource can be controlled at its finest granularity. The Resource Management and Logistics component will not only keep a ledger, using the blockchain, of all the resources we add to it, but will also allow us to establish rules, enforced through the use of the blockchain, that describe how the resources can be sold, transferred or allocated to different internal entities, already defined on the blockchain, or external third parties. The rules will consist of conditions that the deciding agents will impose over each asset that was added as a resource. These conditions, usually called smart contracts, dictate the way a resource can be spent and it allows for automatic resource distribution.

We devise a general protocol which provides a framework for using the Decision Blockchain as a platform for resource management. Using the Decision Blockchain we will ensure the authenticity of the resources and also allow fine grained access control. [27] [28]

In order to better describe the protocols used by the Resource Management and Logistic Component we must first define a few terms.

**Resource Owner:** The blockchain entity (individual, institution, organization) whose actions will lead to the creation of a resource or has been granted ownership over the resource and has control over it.

**End User:** This is the consumer of a resource, who seeks access to the resource but also can verify the ownership of any given resource.

In order for an individual to create a profile they need to be validated by existing Deciding Agents that are part of the User Management institution that runs on the Decision Blockchain.

Once a person is validated a Profile Block is created on the blockchain. The Profile Block will hold personal information, which is hashed to generate a digital signature and the user's private and public keys.

For managing the information in the blockchain we will use a mechanism called Streams. A Stream is a dedicated ledger for certain kind of transactions. A Stream can be used for managing the shared key associated with the signature of any particular user. In the Resource Management Component, we use four streams: S1, S2, S3 and S4.

**Dependency:** a User registers and has a profile created.

**Result:** signature of the user is generated along with the private and public key of the user

**Algorithm 1:** Operations for Signature and Key Generation:

1. A user  $u$  creates profile after registration;
2. The signature  $sig_u$ , for the user ( $u$ ), is generated in the form of a hash from his profile data
3. The Public and Private key of the user  $u$  is generated from the signature, the private key  $pk_u$  is given to the user
4. The signature  $sig_u$ , along with the public key of the user  $sk_u$  is published to the Stream S1;

After a user  $u$  is registered, the user signature and shared key is released to the public via Stream S1, but he is the only one that has access to the private key. After the user has a profile, they can start adding and managing their resources on the Decision Blockchain through the help of the Resource Management Component.

**Dependency 1:** User  $u$  registers and creates a profile for himself;

**Dependency 2:** User owns or has the right to use a certain resource (i.e. document, copyrighted content)

**Result:** Signature of the resource is generated and shared with the owner

**Algorithm 2:** Operations for Resource Creation and Sharing with Owner

1. The signature of the resource is created by hashing the resource content  $D_{uc}$ ; the resource content can be any document stating the ownership of the content as belonging to user  $u$  or the content itself in case it's a digital resource
2. The public key and private key, ( $pk_{Duc}$  and  $sk_{Duc}$ ), are generated from the signature of the resource  $d_{uc}$ ;
3. The signature of the resource  $d_{uc}$  is encrypted with the public key of the resource and is published to S2 along with the signature of the resource owner  $sig_u$ ;
4. The private key of the document  $pk_{Duc}$  is encrypted with the public key of the owner, and the encrypted private key of the document is published to stream S3 along with the id of the resource owner;

After the resource was created and the original owner has access to it, they can share it with any other registered user. If the owner wants to give another user full access to the resource he

will be able to do so by making use of the streams, so the person receiving ownership will have access to the said resource.

**Dependency 1:** Users  $u_1$  and  $u_2$  register and create a profile;

**Dependency 2:** User  $u_1$  owns or has full rights over a certain resource;

**Result:** User  $u_2$  is able to get access to the resource  $D_{uc}$  owned by the user  $u_1$

**Algorithm 3:** Operations for Resource Sharing with another user

1. User  $u_1$  encrypts the private key of the resource and his own signature with the shared key of the user  $u_2$ , and the result will be an access key;
2. The access key together with the signature of user  $u_2$  is published to the Stream S4 by the user  $u_1$ ;
3. The user  $u_2$  using his private key  $pk(u_2)$  can retrieve the resource access key by decrypting the access key published on S4;
4. The private key of the resource  $pk_{D_{uc}}$  is retrieved from the access key by the user  $u_2$ . The private key of the resource  $pk_{D_{uc}}$  can then be used to gain access to the resource stored in Stream S2;

The owner of a resource has the possibility to only allow limited access (for a certain time) to the resource by generating a hash which is time-variant using various hashing algorithms.

### **Logistics using Smart Contracts**

The biggest benefit of blockchain technology is that it can act as a decentralized system and cut out the middlemen. Smart contracts can be used so that automated pre-defined transactions will be triggered whenever certain conditions are met. Smart contracts are stored on the blockchain and all parties can access them using the decentralized system. If anyone tries to alter a smart contract the attempt will be rejected and the stakeholders will be informed. Smart contracts can function like automated lawyers once the infrastructure is in place. Using smart contracts we can immediately receive the documentation generated by the blockchain nodes instead of hiring a lawyer to authenticate and prepare the documentation. [14]

A very popular use of smart contracts is logistics and supply chain management. When a company is involved in manufacturing, shipping and selling their products the supply chain can become very complex and complicated to manage. Using a blockchain system would allow for the data to be standardised so that human intervention will be reduced. A blockchain properly set up to use smart contracts can cover the acquisition of raw materials, tracking of products from the time they are made to the time they are packaged and shipped and many other things so it can replace a lot of other systems that would be needed. (Fig 38). Using the blockchain with smart contracts will allow for fast bottleneck detection and tracking of lost products. When the departments of a company can easily collaborate and optimize the flow of products (Fig 41), complex information and financial transactions between them, excellence in logistics can be achieved. [15]

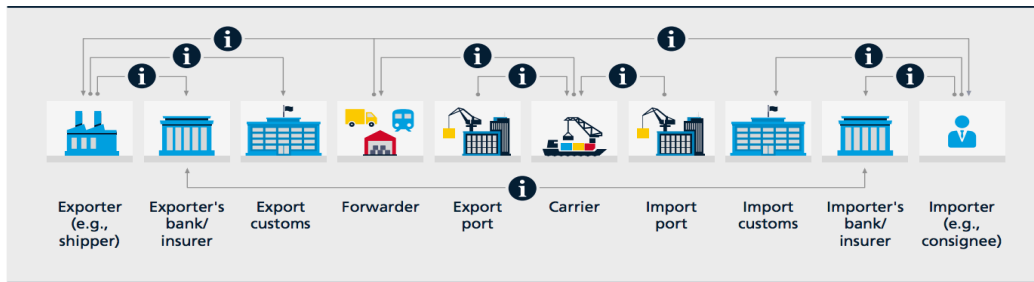


Fig 41: The information flow in international trade is complex, involves many parties, and is documentation heavy

Furthermore, we can achieve cost savings by powering leaner, more automated, and error-free processes. On top of adding visibility and predictability to logistics operations, it can accelerate the physical flow of goods. Provenance tracking of goods can enable responsible and sustainable supply chains at scale and help tackle product counterfeiting. (Fig 42)

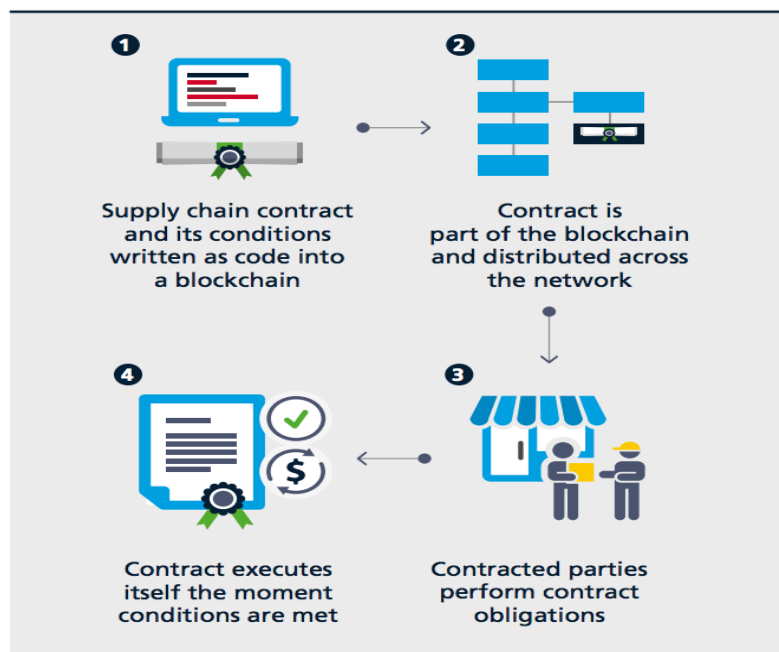


Figure 42: How smart contracts could work in the logistics industry

### MultiChain Platform Specifications

The MultiChain platform streams allow a blockchain to be used as a general purpose append-only database. The blockchain will provide timestamping, immutability and notarization. A MultiChain blockchain can have any number of streams. Data that's published in each stream will be stored by every node. When a node subscribes to a stream it will index the content of that stream so that data retrieval will be efficient. [29]

MultiChain is a platform for creating and deploying private blockchains. It can be used within or between organizations. The purpose of the platform is to solve a key problem to the

deployment of blockchain technology in the institutional financial sector. It does this by providing the privacy and control required in an easy to use package.

MultiChain is derived from the Bitcoin Core software, so it supports Windows, Linux and Mac servers, it also provides a simple API and command line interface.

In order for MultiChain to solve the problems related to mining, privacy and openness it integrates management of user permission. Integrating management of user permissions the following things are achieved:

- Only the chosen participants can view the blockchain's activity
- Controls are introduced that decide which transactions are permitted
- Allows mining to happen in a secure way without proof of work and the costs associated to it

Because the private blockchain participants can control the maximum block size the problems related to scaling will be easily resolved. Another good thing of it being private is that the blockchain will contain only the transactions that are relevant to the participants. In order to understand MultiChain permissions we note that all crypto currencies manage security and identity using public key cryptography.

A user will randomly generate their private key and keep them secret from other participants. A private key has a mathematically corresponding public address that represents the identify using which funds can be received.

When funds are sent to a public address they can only be spent by the person that owns the private key for that address, so they can sign the new transaction. Because of this we can say that whoever owns the private key of a certain address is also the owner of the funds located there.

This type of cryptography, on top of controlling access to funds, can also enable users to sign messages so they can prove they are the owner of the key that corresponds to a particular address. Using this property MultiChain can restrict access to a list of permitted users by expanding the handshake protocol that's used when two nodes connect:

- A node presents its identity on the permitted list as a public address
- A node will verify that the other node address is also on the permitted list
- The node will send a test message to the other node

- The node receiving the test message will send back a signature of the test message so they can prove they own the private key corresponding to the public address they presented
- If the nodes aren't satisfied with the results they will abort the peer-to-peer connection

The idea adding permissions to public addresses on the blockchain can be extended to many other operations on the blockchain network. Using permissions, we can restrict the right to send or receive transactions to a given list of addresses, because transactions reveal the addresses of the senders and recipients. A transaction can only be allowed if all the senders and recipients are permitted.

In some cases it is preferred for the blockchain to be publicly viewable and the restrictions only be applied to transactions. Using a signature fields for the coinbase transactions that are included by miners in blocks, MultiChain mining can also be restricted. In a private blockchain this type of mining restriction could be critical in preventing minority rule.

MultiChain uses special metadata that is contained by the network transactions to grant or revoke privileges. The first miner, that mines the genesis block, will automatically receive full privileges, including the right to manage other user's privileges. Using transactions whose output contain the users address and metadata describing the privileges conferred, the administrator can grant privileges to other users. If the administration and mining privileges of other user are changed, a new constraint is being added, in which a minimum number of existing administrators have to vote to allow the change. The votes will be registered by each administrator using a separate transaction. When a sufficient number of votes are reached the change is applied.

The only exception to this is the setup phase, where the first blocks of a chain added by a single administrator can bypass this voting process. It's also possible that future MultiChain versions can support super administrators that have the rights to assign or revoke privileges on their own.

A stream is an ordered list of items that contain the following characteristics:

- At least one publisher that have digitally signed that item
- A key between 0 and 256 bytes
- A data payload, of several megabytes in size
- Information about the item's transaction and block, this includes its *txid*, *blockhash*, *blocktime*, etc

A MultiChain stream can be referred in three ways:



- An optional stream name, this can be chosen when the stream is created. The name has to be unique on a blockchain, between assets and streams. The names are encoded in UTF-8 format, the size is up to 32 bytes, case insensitive
- A *createtxid* that contains the txid of the transaction where the stream was created
- A streamref that encodes the byte offset of the stream creation transaction, the block number and the first two bytes of the *txid*. When the *root-stream-name* parameter of the blockchain is not an empty string it will define a stream that's created with the blockchain and can be immediately written to. The *createtxid* of the root stream is the *txid* of the coinbase of the genesis block and its *streamref* is 0-0-0

### Streams in transaction data

If you intend to use the MultiChain for regular purposes the following technical details can be ignored, they describe the MultiChain protocol *10007* or later. These technical details are relevant if you intend to work with the raw data inside MultiChain transactions. In order to encode and decode this information we will use the raw transactions APIs.

### Stream creation outputs

A transaction output creates a stream if it contains the following, followed by an *OP\_DROP* (*0x75*) and *OP\_RETURN* (*0x6a*):

Field	Size	Description
Identifier	4 bytes	<i>spkn</i> or <i>0x73 0x70 0x6b 0x6e</i>
Type	1 byte	<i>0x02</i> for a stream.
Property key	Variable	If the first byte of the key is <i>0x00</i> , it denotes a property with special meaning to MultiChain, and the second byte gives the property type. For now, the only possible keys are <i>0x00 0x01</i> , for the stream's name, and <i>0x00 0x04</i> , where a property value of <i>0x00</i> or <i>0x01</i> denotes whether the stream is open to all writers. If the first byte of the property key is not <i>0x00</i> , it contains the null-delimited name of a user-defined custom field, e.g. <i>0x75 0x72 0x6c 0x00 f</i> or <i>url</i> .
Length	1-9 bytes	Bitcoin-style variable-length integer indicating the length of the property value in bytes.

<b>Value</b>	<b>Variable</b>	<b>The property's value as raw binary.</b>
--------------	-----------------	--

A transaction output contains a stream item if it has exactly the following structure:

*stream-identifier OP\_DROP item-key OP\_DROP OP\_RETURN item-data*

**The *stream-identifier* has the following structure:**

<b>Field</b>	<b>Size</b>	<b>Description</b>
<b>Prefix</b>	<b>4 bytes</b>	<i>spke or 0x73 0x70 0x6b 0x65</i>
<b>Stream</b>	<b>16 bytes</b>	<b>First 16 bytes of stream creation txid in reverse order.</b>

**The *item-key* has the following structure:**

The *item-data* is embedded directly after the *OP\_RETURN* and it has no prefix.

### **External key management**

Every participant in a blockchain possesses one or more private keys. The private keys are used to digitally sign transactions relating to the addresses they own. The security of these private keys is very important. If the user has his private key made public, then any other user on the blockchain can forge transactions from that user. This includes spending the assets that user has, changing other users' permissions on their behalf or creating stream items in their name.

MultiChain built-in wallet is used to store private keys by default, this is located in a regular file on the computer where MultiChain is running. Even though the wallet is encrypted on the disk the private key can still be read if the computer is sufficiently compromised. Because of this MultiChain allows for private keys to be stored separately, like in a hardware security module. The external private can can be generated randomly by MultiChain by using the API command *createkeypairs* or using an external bitcoin compatible library.

MultiChain can track the activity of an address by using the API command *importaddress*, without needing its private key. MultiChain can also use using the *createrawsendfrom* API build an *unsigned* transaction for imported addresses.

There are two ways to sign a transaction. The first is by using a regular MultiChain node's *signrawtransaction* API command. The private keys are passed as a parameter then the result is passed to *sendrawtransaction* for broadcast. This method exposes the private key to MultiChain but it will not be stored on the disk.

A safer method, but also more complex, is to sign the transaction outside of the MultiChain node and using *sendrawtransaction* to broadcast the signed transaction. This can be done with MultiChain or using an external software library or hardware device that can unpack raw transactions and add signatures to their inputs.

Because MultiChain uses bitcoin's transaction structure and cryptography we can use any bitcoin compatible library or device. [30]

## 5. Component Design and Functionality

---

The Decision Making Environment Components are designed to integrate the most intuitive design paradigms currently being used in the software development industry. When it comes to functionality and the interaction between them, we try to create a virtual ecosystem mimicking the organic relationships between body organs and relevant cell interactions.

As previously mentioned in Chapter 4 we are going to present the individual components that make up the generic architecture we described. These components are: *Trust Rank Component*, *Legislation Creation Component*, *Feed - News and Organic Developments Component*, *Issue Framing Component*, *Feedback Component*, *Bayesian Decision Making and Swarm Decision Making Component* and of course the *Decision Blockchain*.

### 5.1 Trust Rank Component

In order to facilitate the identification of valid candidates and the creation of organic hierarchies based on the traits relevant to the process of governance or decision making we propose a dual voting system.

The first aspect that will be measured is the trust level of each individual and the second is the audacity and relevance of his arguments, also known as wisdom. For this we provide a direct vote of trust to any individual you consider trustworthy in the case yourself don't want to be implicated in the governance or decision making process. The vote of trust will be singular, that means you can only give it to one person, and it can be taken back after a period of time, lets say 3 months, so we don't create changes that are too frequent in the organically created hierarchy and also make the person more responsible for their vote.

The people at the top of the trust hierarchy will be viable candidates for the executive branch of government or the agents that act out the implementation of the law and manage the institutions created for monitoring the correct impl [5]ementation of the law.

For the Legislative branch we will create a hierarchy based on a peer validated voting system - when you up-vote/down-vote any issue or idea you also have to provide a reason for the vote, if the reason for the vote can't be defended against public scrutiny the vote will be invalidated. Users can argue against a vote and if the arguments are compelling and convince others that the vote argument isn't valid it will be invalidated. So if an argument against a vote that was given

for whatever reason gets more up-votes than the vote itself, after a period of time depending on how many users voted on it and the ratio between up-votes and down-votes the vote will become invalid. [2]

With this kind of voting system we can keep the advantages of weighted vote and at the same time keep democratic universal voting. You can vote but it doesn't mean your vote will actually count if the reasons behind it aren't relevant. One of the main reasons for voting is to achieve clarity regarding a certain problem by querying the collective wisdom, whatever we can do to filter out unwise or irrational people will bring more value and credibility to the result of the vote. Quantifying the power of a voter relative to the clarity and rationality of his arguments is a good way to refine the voting pool and create a hierarchy based on objective values.(Fig 43)

Trust Rank	Team Name	Votes of Trust
1	Nicolae Tapus	266
2	George Dumitru	264
3	Aurel Gheorghe	262
4	John Doe	260
5	Bob Dylan	256
5	Ramona Jalba	256
7	Alice Birsan	254
7	Diana Petre	254
9	Monica Buciuman	250
10	Joshua Christopher	248

Fig 43. Example of Trust Ranking Based on Votes of Trust

The up/down-voting algorithm is based on the votes of trust the user has and they are applied to each item being voted on (Fig 44).

```

/* weighted vote algorithm for a specific post or comment */
voteItem = function(user, item, vote) {
  if (vote > 0) {
    item.ups += vote * user.trustRank;
  } else {
    item.downs += vote * user.trustRank;
  }
};

```

Fig 44. Weighted vote scoring algorithm

The algorithms used for sorting by confidence and popularity using the votes of trust are derived from the Wilson confidence score (score interval) and Reddit popularity sorting (Fig 44). Edwin Bidwell Wilson (April 25, 1879 – December 28, 1964) was an American mathematician and polymath. In 1927 he introduced the Wilson score interval (Fig 45), a binomial proportion confidence interval, and also derived the "plus four rule", which uses a pseudo count of two (add two to both your count of successes and failures, so four total) for estimating the probability of a Bernoulli variable with a confidence interval of two standard deviations in each direction (approximately 95% coverage).

```

/* comment position based on wilson confidence score */
wilsonScore = function (z) {
  if (z == null) {
    // z represents the statistical confidence
    // z = 1.0 => ~69%, 1.96 => ~95% (default)
    z = 1.96;
  }

  return function (ups, downs) {
    var n = ups + downs;
    if (n === 0) {
      return 0;
    }

    var p = ups / n;
    var sqrtexpr = (p * (1 - p) + z * z / (4 * n)) / n;
    return (p + z * z / (2 * n) - z * Math.sqrt(sqrtexpr)) / (1 + z * z / n);
  };
};

```

Fig 45. Wilson score interval algorithm

```

/* post popularity score based on up-votes/down-votes */
redditHot = function (decay) {
  if (decay == null) {
    decay = 45000;
  }
  return function (ups, downs, date) {
    var s = ups - downs;
    var sign = Math.sign(s);
    var order = Math.log(Math.max(Math.abs(s), 1)) / Math.LN10;
    var secAge = (Date.now() - date.getTime()) / 1000;
    return sign * order - secAge / decay;
  };
};

```

Fig 46. Sort by popularity algorithm

Using an adapted version of the prioritization algorithms, like Reddit Hot (Fig 46), enables a faster and more reliable way of identifying and solving problems

The JSON config object for the Trust rank component contains the following flags:

```
trust_rank_component_config: {  
    enabled: true/false, // activate or deactivate the trust rank component  
    vote_of_trust_min_life_time: number, // minimum time a vote of trust remains valid  
}
```

### Trust Rank Component Support

Based on the organisms principle as well as the self similarity property of fractals we uses the human nervous system (Fig 47) as an inspiration to create the Trust Rank Component.

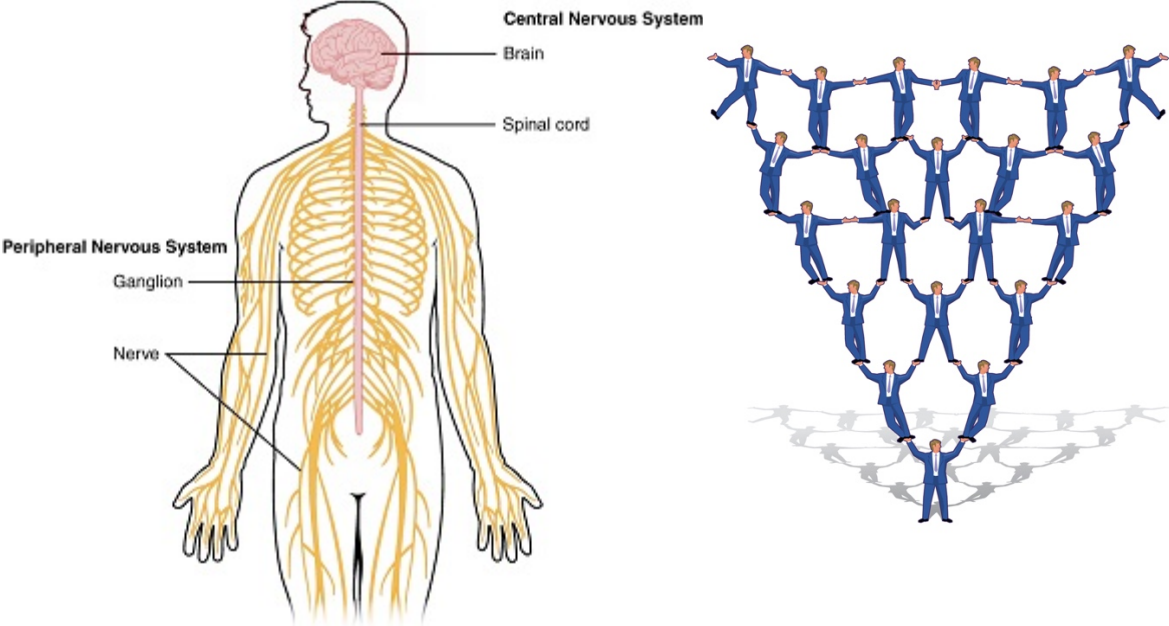


Fig 47. Human Central Nervous System and the Trust Hierarchy

The human nervous system is made up of nerve endings, nervous ganglions, the spinal cord and the brain. The nervous system of the human body creates an organic hierarchy (Fig 45) where the closer you are to the brain the more decision power you have over the body. In order to achieve the same level of reliability for our decision making environment we chose Trust to be the decisive quality based on which the organic hierarchy will be created.

When it comes to quantifying trust there is no formula or algorithm that we can rely on that will pick for us the person we trust the most (Fig 48). That’s why we must allow all members that

will make use the decision making environment to choose the person they trust the most, based on their own subjective reasoning and feelings, or keep the vote of trust for themselves and become involved in the decision making process.

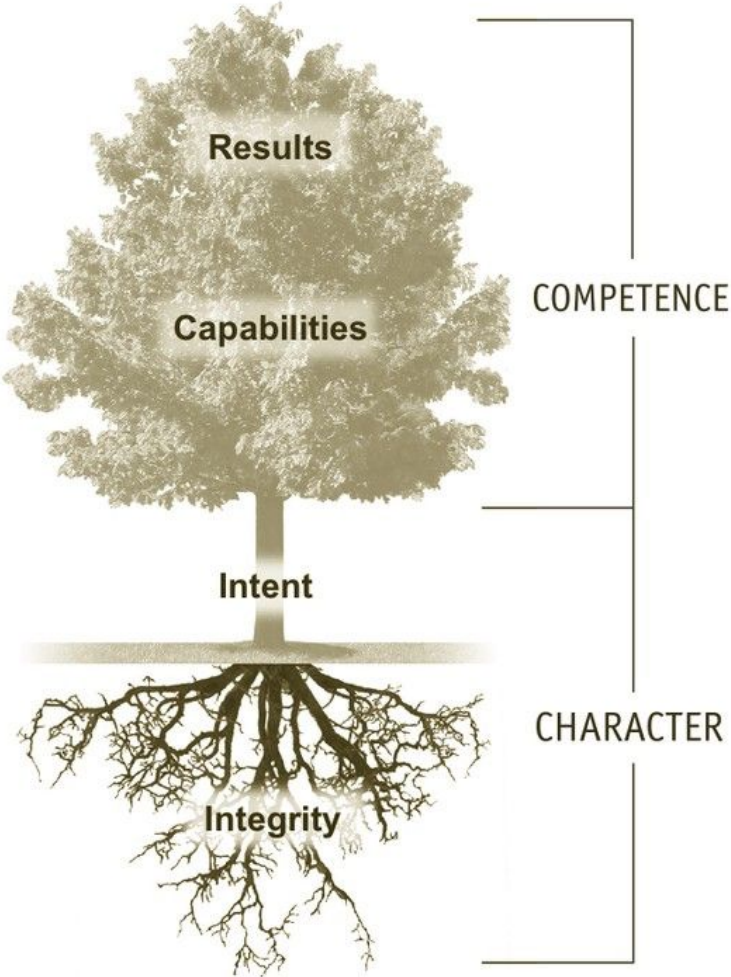


Fig 48. Anatomy of Trust

### 5.2 Legislation Creation Component

The current way of creating new laws and rules is very inefficient because most of the time it doesn't allow for the majority of those impacted by the laws being created to take part of the creation process in the form of suggestion and for those that actually are part of the creation process cooperation is very difficult because there is no way for all of them to equally intervene in the process. In order to address this issue we propose a collaborative legislature creating interface in which each law is split into smaller units called **law atoms**, which can vary in length from one sentence to one paragraph. Each of these law atoms will be saved inside a



Decision Block so they can be changed independently from one another. A law article will include many of these law atoms which can be voted upon individually and edit suggestions can be added to each atom and the suggestion list will show up as alternatives when you select a certain law atom. People will be able to vote on these suggestions and if a suggestion gets a certain number of votes the atom will be replaced with that suggestion. This way all people involved in the lawmaking process will have equal power of influence over the law being created and only the best ideas will actually make it in the law. After a law draft is finished it can be peer reviewed by the people that the law will affect and issues and suggestions can be raised that will reach the people in charge of actually creating the law.

When the law receives enough public support it will become ready for publication and at a certain date determined in the creation process it will become active. Each law atom will be saved in the blockchain as a decision so that anyone at any time can check the creation history of any given law and at the same time assure it's safe keeping.

The Legislation Creation Component (Fig 49) mimics in functionality the organic gene editing mechanisms of live organisms and offers an intuitive interface to translate complex laws and regulations into small fragments which are called law atoms that are going to be stored into the Decision Blockchain.

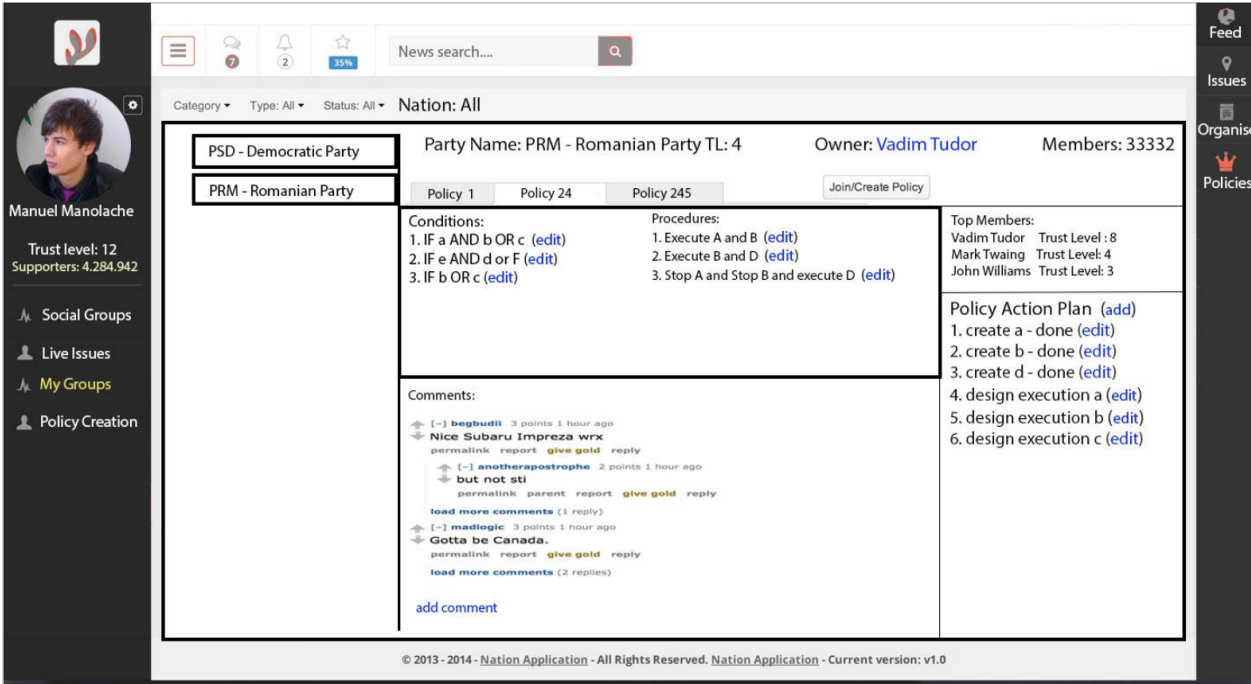


Fig 49. Dynamic Policy and Legislation creation component GUI using the Decision Blockchain

The JSON config object for the Policy Framing component contains the following flags:

**policy\_creation\_component\_config:** {

**enabled:** true/false, // activate or deactivate the issue framing component

**enable\_weighted\_vote:** true/false, // enable weighted vote

**force\_smart\_contracts:** true/false, // flag to enable or disable smart contracts for each adopted rule/law that will be saved on the blockchain

**maximum\_group\_size:** number, // specifies the maximum number of members that can join a policy creation group

**minimum\_trust\_rank:** number, // minimum trust rank needed for a member to join a group

}

### **Legislation Creation Component support**

The Legislation Creation Component will be based on way the human brain learns and makes sense of the world, using neural connections, circuits and networks. A neural circuit is a population of neurons interconnected by synapses to carry out a specific function when activated. Neural circuits interconnect to one another to form large scale brain networks.

In order to understand how the Legislation Creation Component works we will analyze the way the human brain behaves when trying to find the solution to a problem.

The first phase is to categorize the problem. For this first problem recognition phase the brain uses a heuristic method and tries to find a best match over all previous experiences.

After the problem is categorized, in the second phase, the brain starts to identify the factors or parameters that generate the problem and tries to find a match in terms of used parameters so that it lowers even more the solution space. Once it has a good handle on the solution space the third phase begins.

In the third phase the brain tries to converge to a single solution, or in some cases, when the brain is more evolved, to a dynamic solution space. In order to find the best solution for the problem the brain starts firing different electric signals that encode the problem and a set of generating parameters over as many neural networks as possible that make up the solution

space. Each of these networks will adapt the initial electric signal to match their input and if the output converges to one value it means the brain found a solution or match.

In this last step there are three different outcomes:

- it either identifies a concrete solution that can be applied as it is
- it will heuristically generate a new neural network that returns the solution based on previous solutions to similar problems
- it will not find a solution but it will allocate a solution space, made up of neural networks that get closest to converging to a solution based on the input signal, that will later be explored when more data will be available, to either identify more generating parameters or create additional correlations between existing parameters and effects.

Our Legislation Creation Component will act as an interface for the second outcome, where a solution is being generated by using previously solved similar problems. In order to store the data about problems and solutions, create new ones, and enforce existing ones we will use the Decision Blockchain and Smart Contracts.

The Decision Blockchain will store each logical proposition that make up a law atom and represent a neural connection allowing us to have the finest level of granularity over the laws that govern our decision making process and at the same time give us complete flexibility when it comes to tweaking and adjusting existing solutions. The smart contracts provide a proactive way for the existing logic that's present in each law atom to be applied to every new decision being taken. This way new decisions will automatically adhere to the existing laws. For this each Input and Output of a decision will be described in a Description Block and based on the Decision Blockchain Protocol the Inputs and Outputs will automatically be chained together among different laws.

## 5.3 Feed – News and Organic Developments Component

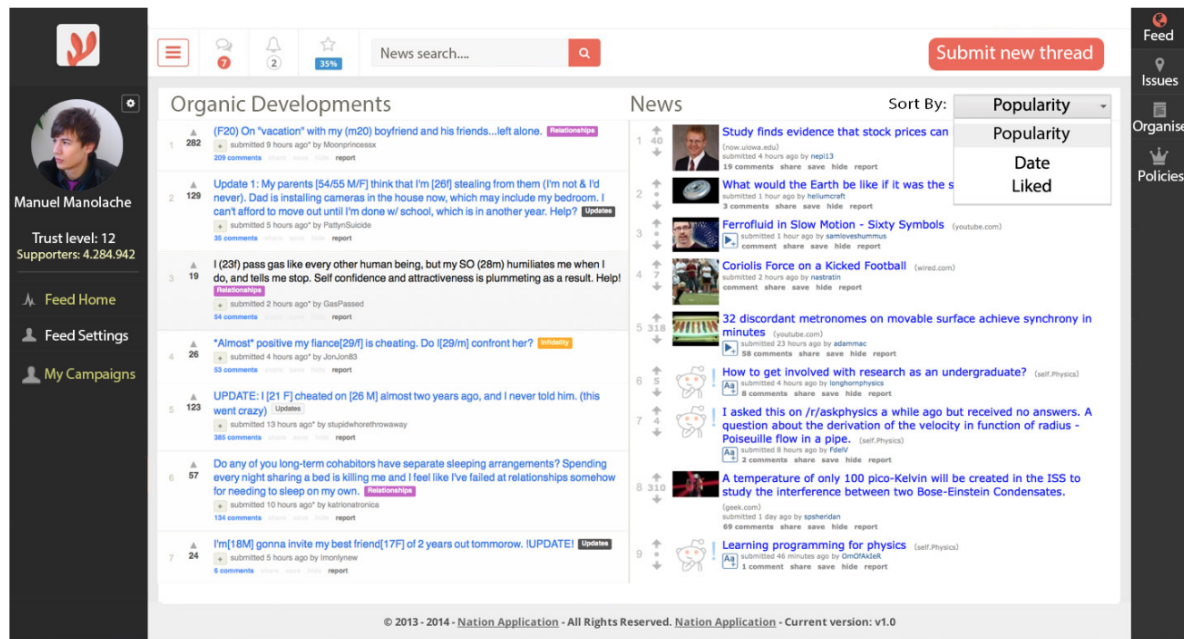


Fig 50. Feed - News

In the News category (Fig 50) users can submit information which is relevant to the whole society, like inventions, theories, studies, scientific articles, major social events, and so on. [4]

The News category acts like a parasympathetic ganglion, without having any reaction attached to it, only monitors and broadcasts information for the whole human society to see.

Any individual can post in the News feed because the voting system will place the news at its right place as soon as other members categorize it as relevant or irrelevant.

The News feed can also be used to point to resolutions for other ongoing issues that Groups and Organizations try to solve or create policies for. If a Policy needs to be created to handle traffic in crowded areas but there is an Article in the News section that talks about Artificial Intelligence Traffic Management, the Group that is trying to develop a solution can reference that News article and bring the people involved with that discovery into the policy creation process and later on create a public Project for the solution to be implemented using that technology.

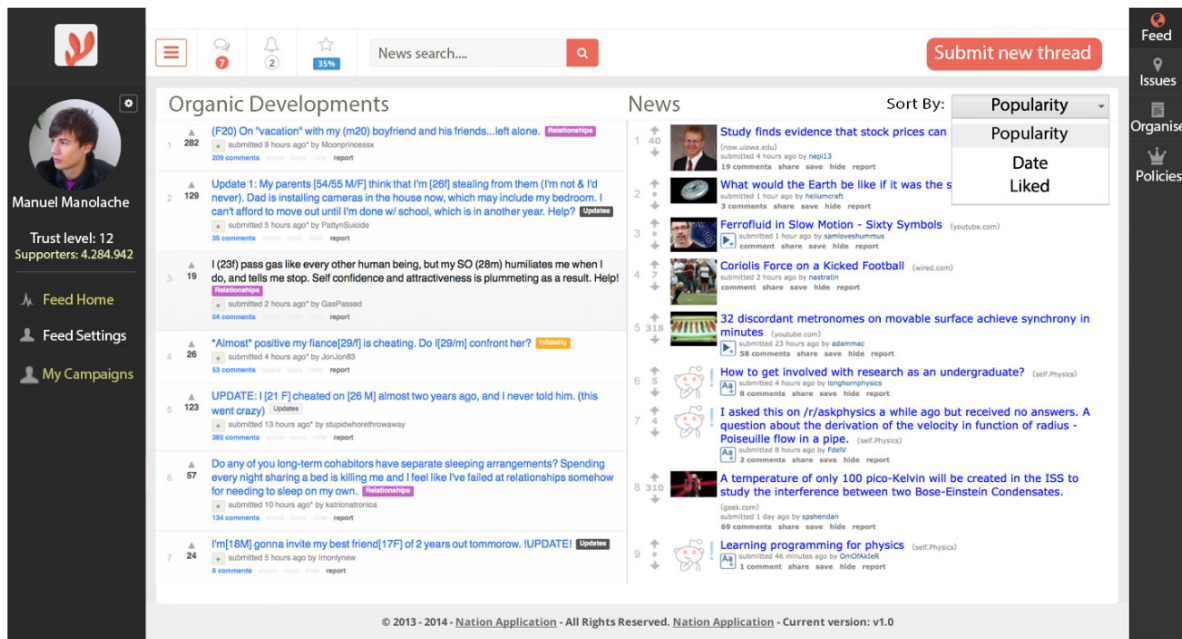


Fig 51. Feed – Organic Developments

Organic developments (Fig 51) allows for everyday personal issues to be submitted so the community can collaborate into finding solutions. Organic development threads can consist of any type of issue someone can meet in his daily life, from relationship problems, infrastructure development, public transport issues, and even emergencies of any type like fires, car crashes, and so on.

In the Organic developments sections articles are going to be down-voted or up-voted depending on the relevance and also on the area of impact each issue has. If on residential area there is an urgent need for extra parking spaces someone can Submit a thread regarding it and invite all people living in that area to up-vote it. If the number of votes in a specified period of time reaches a certain threshold the criticality of the issue is increased and a message will be sent to Organizations and Parties that work in that specific area. Hashtags are going to be used to signal the area of expertise and other such properties for each Organic Development.

Once an Organic Development reaches a certain criticality, Organizations and Parties can address it and start creating Policies or Projects that will fix the issue and assures no other future issues of that nature can arise and if they do an automated plan of action will be used and laws to prevent that will become active.

If a fire starts in a Petrol Station a Policy can be drafted that forbids people from using fire in a certain area around a Petrol Stations. Another example of Organic Development can be people complaining there are no parking spaces around some area, once the Issue is upvoted to reach

a critical priority level, an Organization can address the Issue and create a City Project that can build fast parking spaces using available technology, which will be used for all issues of that sort around the City.

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Any individual can post in the News feed because the voting system will place the news at its right place as soon as other members categorize it as relevant or irrelevant.

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## **5.4 Issue Framing Component**

Issue framing is a vital part of the decision making process because it describes the problem we are trying to solve and a problem well-stated is a problem half-solved. In order to achieve the greatest efficiency in solving problems that are raised by the organization being governed we must separate the process of collecting issues into sub processes that work together to filter and prioritize the collected problems.

The first layer of filtering should be done organically by the masses using the trust rank voting system, the more people with high trust rating vote for an issue the more exposure it gets. [4] If a raised issue gains enough traction and popularity it will trigger the second layer of filtering in the issue framing process. The second layer of filtering should be done by the people with the highest trust rank that were directly involved with the issue by voting or indirectly connected to the issue through people that voted on it. So if I have a high trust rank and up-voted for an issue or a person that gave me their vote of trust voted for an issue, I will automatically be involved in solving it as being the person with the highest trust rank in that context.

People with the highest trust rank can then decide to escalate the problem by framing it as a public issue so the higher levels of governance will become responsible to solve it, or they can address the issue themselves, together with the structures of governance they are in direct contact with.

The Issues section can be seen as a bug reporting application like Jira and Bugzilla but instead of reporting software bugs we report real life issues that are derived from the Organic Development Feed that reached a certain level of popularity and have groups of specialized citizens, parties or financial organizations find fixes for them.

T	Category	Summary	Assignee	Reporter	P	Status	Resolution	Created	Updated
	Education	British Education designed to polarize people	Rafael Antelo	Mihai Istrate	🔴	OPEN	Unresolved	04/Feb/14	04/Feb/14
	Healthcare	New anti AIDS vaccine	mher sargsyan	mher sargsyan	🟢	OPEN	Unresolved	03/Feb/14	03/Feb/14
	Healthcare	DNA manipulation for eye color changing	Rodrigo Pinto	Mihai Istrate	🟢	OPEN	Unresolved	01/Feb/14	01/Feb/14
	Social	Happiness level dropped in New York	Rodrigo Pinto	Mihai Istrate	🔴	OPEN	Unresolved	30/Jan/14	30/Jan/14
	National Security	Teleportation devices for police officers	Rodrigo Pinto	Mihai Istrate	🔴	OPEN	Unresolved	29/Jan/14	29/Jan/14
	Technology	Time travel machine based on vortex physics	Mihai Istrate	Mihai Istrate	🟢	CLOSED	Fixed	29/Jan/14	29/Jan/14
	Entertainment	Extra terrestrial TV stations	mher sargsyan	Teodor Sandulescu	🔴	OPEN	Unresolved	29/Jan/14	03/Feb/14
	Environment	Artic ice cap shrinking	mher sargsyan	Teodor Sandulescu	🔴	OPEN	Unresolved	28/Jan/14	29/Jan/14
	Lifestyle	Need more cinemas in Bucharest	mher sargsyan	Teodor Sandulescu	🔴	OPEN	Unresolved	28/Jan/14	29/Jan/14
	Transport	Intergalactic travel to Andromeda is too slow	mher sargsyan	Teodor Sandulescu	🔴	OPEN	Unresolved	27/Jan/14	29/Jan/14

Fig 52. Issues List

On the Issue List (Fig 52) page users can see a list of Issues that match their personal settings, like Location, Tags, Categories, ordered by different fields. Each Issue can be created by party or organisation members and can be derived from an Organic Development that become popular.

Once a party member opens an Issue or gets invited by another party to join solving an issue it will show up in their Group followed Issues so they can discuss and find solutions together with their group.

Users can request email updates for the issues they are following by setting it up in the Settings Page.

The interaction between regular users and any ongoing issue is limited to only commenting. Party and Organization members can come up with solutions in the form of laws, campaigns, projects, meetings and so on, with the purpose of fixing the issue and any other that can eventually arise of the same type.

Once an issue was solved the status will change to Closed. If the users wants to find out more information they can click on the Issue and go to the Issue page where all the details regarding it will be displayed.



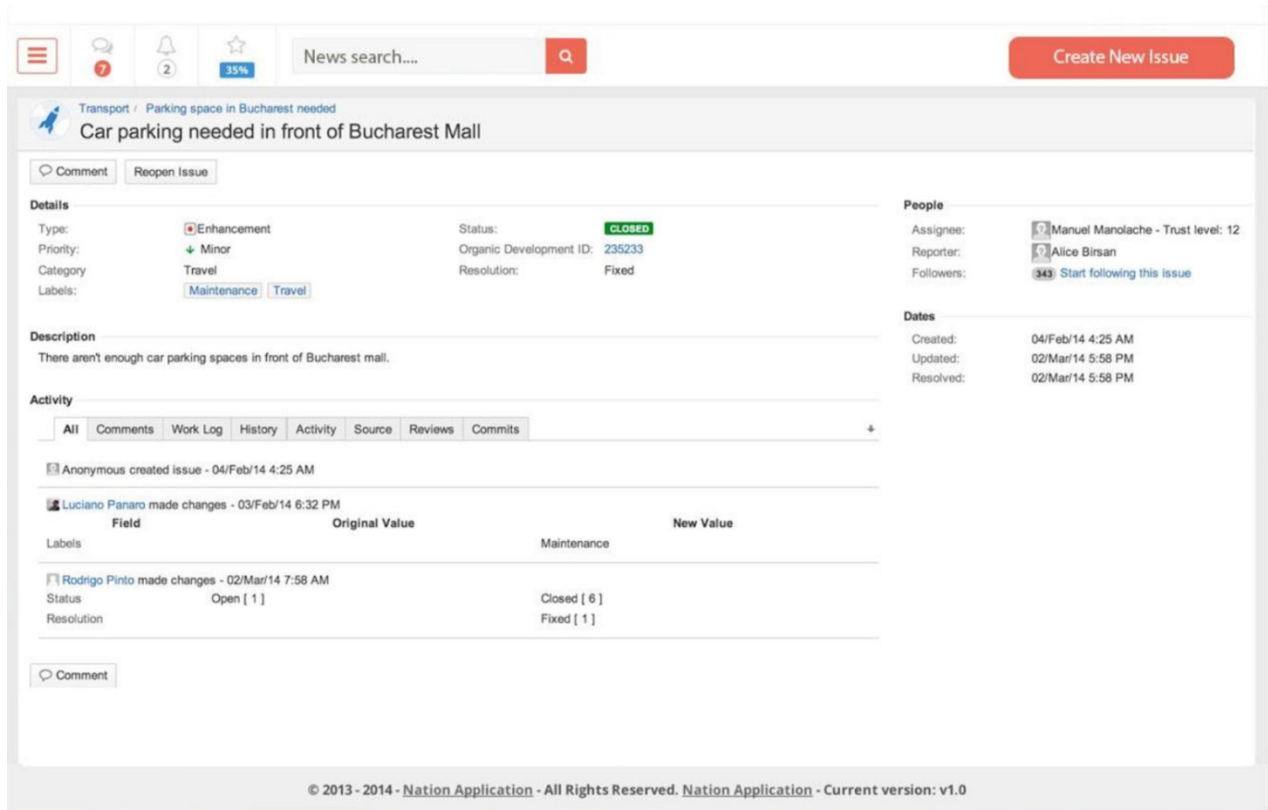


Fig 53. Issues Page

On the Issue Page (Fig 53) Users have access to all details regarding the Issue like, Category, Priority, Tags, Status, Number of followers, Comments, Groups, Commits done by different Groups and Organizations, Source for the current solution and so on.

If any regular user wants to help they can do so using the Comments section, in the Comment section any relevant comment can be up-voted so everyone will be made aware of relevant information that was submitted by anyone following the Issue.

In the Work Log we can see what each Group or Party is working on related to the Issue and their latest conclusions.

In the History Tab we can see time labels referring to groups joining the Issue, submitted partial solutions, and other relevant information sorted by the date of submission.

The Activity Section will display Actions started by the Groups or Parties in order to find a solution like meetings, information gathering, research.

The Source Tab contains the latest accepted partial solution from which other joining Parties can start and branch to improve on.

The Reviews Section allows users from all parties to collaborate in discussing the partial solutions they found so far and post reviews to each other's solutions.

The Commits Section will show a list of committed material like legislation, projects, meetings, that are considered to be a solution for the Issue at hand.

Once a solution is considered complete by the majority of following Parties and Individuals the Issue will be flagged as Fixed and the solution implemented in the circle or area the Issue can appear, for a street, a Corporation, for a whole City, or Nationwide.

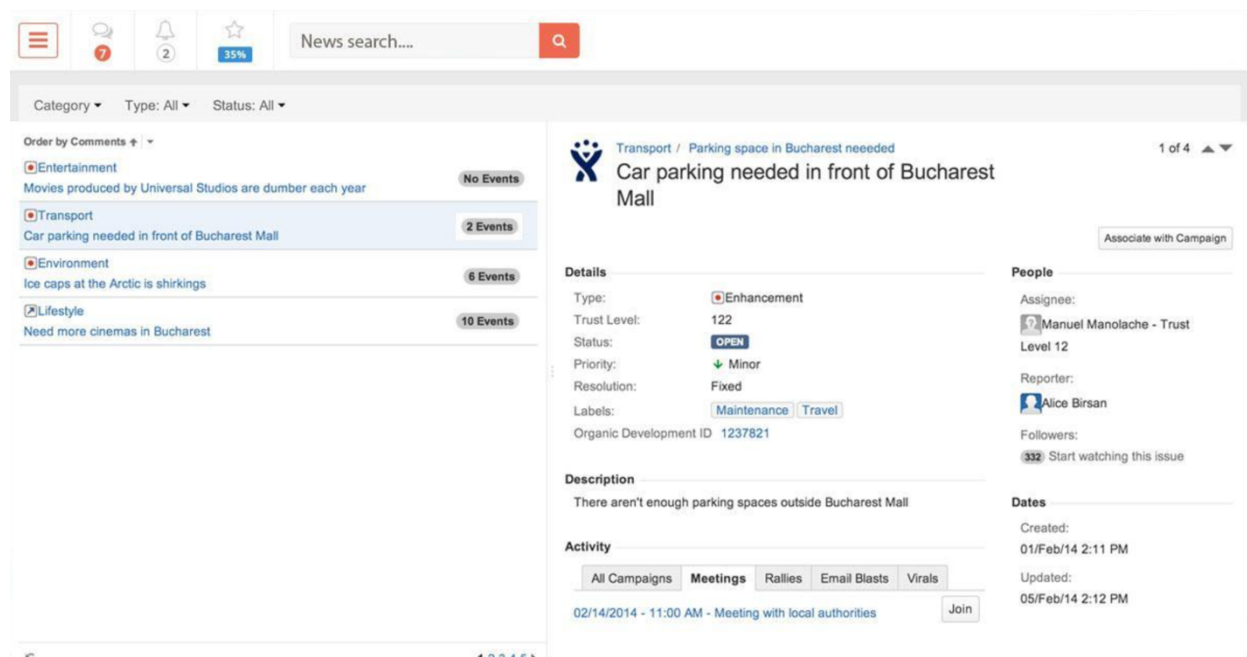


Fig 54. Followed Issues Page

Once a member opens an Issue or gets invited by another party to join solving an issue it will show up in their Followed Issues page (Fig 54) so they can discuss and find solutions together with their group. Users can request email updates for the issues they are following by setting it up in the Settings Page.

The JSON config object for the Issue Framing component contains the following flags:

```

issue_framing_component_config {
    enabled: true/false, // activate or deactivate the issue framing component
    enable_weighted_vote: true/false, // enable weighted vote
    allow_issue_pinning: true/false, // flag to enable or disable issue pinning
}

```

## 5.5 Bayesian Decision Making and Swarm Decision Making Components

When experts that are part of a group have to solve a problem they think about it in very different ways, so their opinion regarding the decision that has to be made differs even though they are referring to the same situation. [5]

In order to allow different experts to work as a cohesive group we can use a Bayesian Network so that even though they might have different solutions they will be able to identify a causal relationship between the variables inside the Bayesian Network and quantify the graphical models with numerical probabilities. Even when facing a simple problem the approach of different experts as well as their knowledge can be very different. Without an objective and quantifiable way of comparing and sharing the different solutions and approaches it's virtually impossible for experts to come to an unanimous decision. [6] [7]

The framework and methodology we propose involves transforming the collective wisdom into a set of decision making statements that are dependent on identified probability constraints used for inference in a Bayesian Network.

Using the Bayesian Network decision making interface (Fig 55) users are allowed to add belief factors that they consider most influential in determining the success probability of a given decision. In the case of ordering a pizza the user has the possibility of adding all ingredients as well as their probability to generate a favorable outcome. By combining the belief factors of members we can obtain an accurate representation of the collective preference regarding the ingredients that should go on a pizza for it to be considered delicious. The Bayesian Network interface for decision making is preferred to be used in cases where we have to deal with quantifiable parameters.

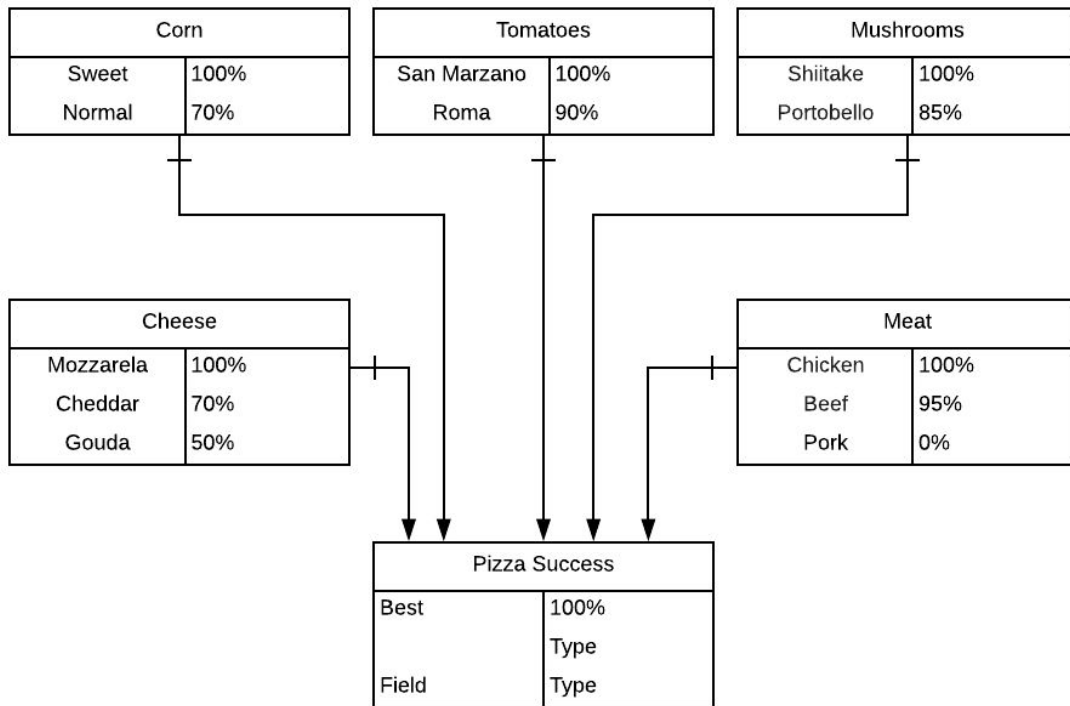


Fig 55. Bayesian network interface An alternative to using the Bayesian Network decision making interface is using a simpler

The Swarm Decision Making interface (Fig 56) is better suited for decisions that depend on subjective beliefs or feelings that can't be easily quantified. Also the decision making process in the case of the Swarm Decision Making interface is faster and happens in real time. The real time negotiation being done through an intuitive interface and not numerically as in the case of the Bayesian Network.

As an example, when choosing between some presidential candidates we can see how each individual taking part in the voting process is represented by a magnet which can be moved towards the candidate they prefer mostly. If the candidate they prefer can't be reached because the other voters go in other directions, the user can still influence the result of the vote by choosing to support some of the others more viable candidates.



Fig 56. Swarm Decision Making interface example [7]

The decision making interface config file will have the following structure:

***decision\_interface\_component\_config:***{

***enabled:*** true/false, // activate or deactivate the issue framing component

***enable\_relative\_weighted\_vote\_strength:*** true/false, // enable weighted vote strength so users with higher votes of trust can have greater influence

***maximum\_group\_size:*** number, // specifies the maximum number of members that can make a decision using the interface

***minimum\_trust\_rank:*** number, // minimum trust rank needed for a member to join a decision making session

***max\_number\_of\_options:*** number, // number of maximum options that can be decided from

***enable\_complex\_interface:*** true/false, // flag to enable/disable the Bayesian decision making interface

}

## 5.6 Feedback Component

One of the most important components of a decision making environment is the feedback component. The feedback component is suppose to measure the success of the decisions being taken using the platform and provide an objective scale that we can use to compare different decisions and how they impact the governed population. The algorithm used for such a component can be inspired by the “Felicific calculus algorithm”, which was formulated by utilitarian philosopher Jeremy Bentham (1748–1832) for calculating the degree or amount of pleasure that a specific action is likely to cause. Bentham, an ethical hedonist, believed the moral rightness or wrongness of an action to be a function of the amount of pleasure or pain that it produced. The felicific calculus could, in principle at least, determine the moral status of any considered act. Included in this calculation are several variables (or vectors), which Bentham called "circumstances".

These are:

**Intensity (I)** - How intense is the pleasure or pain?

Bentham apparently thought intensity would vary from zero to infinity, but psychological data indicates an upper threshold of pleasure; hence, we can use an ordinal relation from 0 to 10. Pain could be measured in the same manner, where for both pleasure and pain, 0 represents indifference.

**Duration (D)** - How long does the pleasure of pain last?

We can use increments of time: seconds, minutes, and so forth. The time interval from the perceived beginning of the pleasure until the end of the pleasure in question.

**Certainty (C)** - What is the probability that the pleasure or pain will occur?

The assigned probability can be drawn from records of our past experience and records from persons similar to us. What proportion of times has the pleasure followed actions of the kind under consideration?

**Propinquity (N)** - How soon will the pleasure occur?

We can set up a future indifference curve based on a "store of satisfaction" such as money (q. v., below). Propinquity of pleasure depends upon how long one must wait for the pleasure to occur.

**Fecundity (F)** - The probability that the action will be followed by sensations of the same kind

The probability that the pleasure or pain will lead to other pleasure or pain of the same kind can be drawn from records of our own past experience and the past experience of others like us. Also, as the Epicureans noted, many extreme pleasures are not likely to be followed by other pleasures.

**Purity (P)** - The probability that it will not be followed by sensations of the opposite kind. Bentham writes, "Of the value of each pain which appears to be produced by it after the first. This constitutes the fecundity of the first pain, and the impurity of the first pleasure."

**Extent (E)** - How many persons are affected by the pleasure?

The total amount of utility or pleasure can be had by summing a similar calculation for every other person who is affected by the action in question.

On top of the existing variables we will also need an additional parameter to describe the **Polarity (R)** of the feedback, as either positive or negative. The polarity would allow us to determine if a Decision Block had a positive or negative effect on the affected population, and together with the rest of the parameters that go into the felicific calculus formula we can quantify the amount of pleasure or pain inflicted in order to obtain an objective scale of measurement for how a decision's value changes from iteration to iteration. Because a complex evaluation is not always required or some users might prefer to give a simple feedback we will have two Feedback Types: Simple Feedback and Extended Feedback.

### **Simple Feedback**

The Simple Feedback (Fig 57) will provide a very intuitive interface consisting of a slider with a smiley face that progresses from sad to happy depending where it is positioned. For simple feedback we will insert values for each parameter of the felicific calculus algorithm relative to the position of the slider, starting at -1 for completely unsatisfied going up to +1 for completely satisfied.

The interface for such a slider is built in Javascript using the Canvas element, the movement of the slider will be tracked using the `onmousedown`, `onmousemove` and `onmouseup` native callback functions. Whenever the smiley face is moved we will redraw the mouth and eyes according to express the corresponding emotion according to the position of the slider.

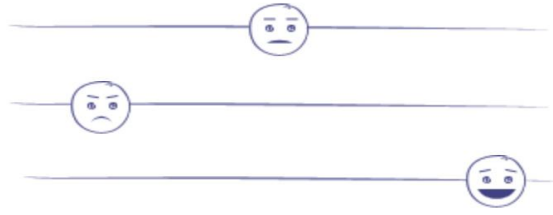


Fig 57. Simple Feedback Slider Interface written in Javascript

### Extended Feedback

The Extended Feedback (Fig 58) will provide an interface of multiple sliders where users can input each of the parameters relevant to the Felicific Calculus. The Extent (E) parameter will be automatically extracted from the Decision Blockchain and it represents the number of people affected by a decision.



Fig 58. Extended Feedback Interface

### Feedback Formula

The formula for computing the Feedback score (Fig 59) is based on the Felicific Calculus parameters and adapted to be used for the Decision Blockchain. Each variable has a weight depending on its relevance and use the **Polarity(r)** parameter to give the sign of the final result.

$$fs(r, i, d, c, n, f, p) = r \times c \times \left( \frac{i}{4} + \frac{d \times i}{2} + \frac{f}{8} + \frac{p}{8} \right) - \left( \frac{n \times c \times r}{10} \right)$$

Fig 59. Formula for calculating the feedback score of one user



Using the **Feedback Score (fs)** formula (Fig 60) we calculate the score for a specific Decision Block. To calculate the score for a Decision Block we calculate the average of all feedback scores that were submitted.

$$\frac{\sum_{k=1}^n fs(r_k, i_k, d_k, c_k, n_k, f_k, p_k)}{n}$$

Fig 60. Formula for calculating the feedback score for a Decision Block (n - total votes)

### **Feedback Component Configuration**

The Feedback Component will be used to gather feedback from the governed body, measure the success of the decisions being made using the platform and provide an objective scale that can be used to quantify the success of different decisions, how they impact the satisfaction of the governed population and how they affect the performance related to reaching the goals derived from the purpose of the group using it.

The factors relevant for configuring the Feedback Component are:

- System complexity: if the integrated decision making environment will be used by a large organization with a complex internal structure then it's vital to receive complex feedback from all members to fine-tune the decision making process.
- Products and services being delivered by the organization using the platform: in cases where the products or services being delivered by the organization can be improved if internal feedback is gathered.
- Importance of member satisfaction: if the members that constitute the governed body are also the beneficiaries of the products and services the organization provides, the feedback component needs to be enabled.
- The decision making process inside the organization depends on accurate internal information: when the performance of the organization depends on how accurate the internal information is the usage of the feedback component will highly increase the performance of the operations and quality of products delivered by the organization

The structure of the JSON object that's being used by Configuration Module to store settings for each component will have an attribute called `feedback_component_config`. The feedback component will have the following parameters:

```
feedback_component_config: {  
    enabled: true/false, // flag that turns on or off the feedback component  
    min_trust: number, // the minimum number of votes of trust needed to use the feedback  
component  
    feedback_type: 'complex'/'simple'/'both' // specifies the mode of operation of the  
feedback component, to use the simple interface, the complex interface, or allow both  
}
```

### **Feedback Component Theoretical Support**

The Feedback Component was inspired by the biological principle of homeostasis and feedback loops. Without feedback, homeostasis cannot occur. This means that an organism loses the ability to self-regulate its body. Negative feedback mechanisms are more common in homeostasis, but positive feedback loops are also important.

In biology Homeostasis is the tendency of an organism or cell to keep a constant internal environment and maintain equilibrium, usually by a system of feedback controls, with the purpose of stabilizing health and functioning. A body is in homeostasis when everything is functioning properly and its needs are met.

Homeostasis is kept using a complex set of thermal, chemical and neural factors by all organs of the body that interact in complex ways by helping on hindering the body, with the purpose of maintaining homeostasis. [31]

In order for homeostasis to be maintained communication within the body is essential. In the image below(Fig 61) we have an example of how a homeostatic control system functions. Also we will further explains each of the components that make up the homeostatic control system.

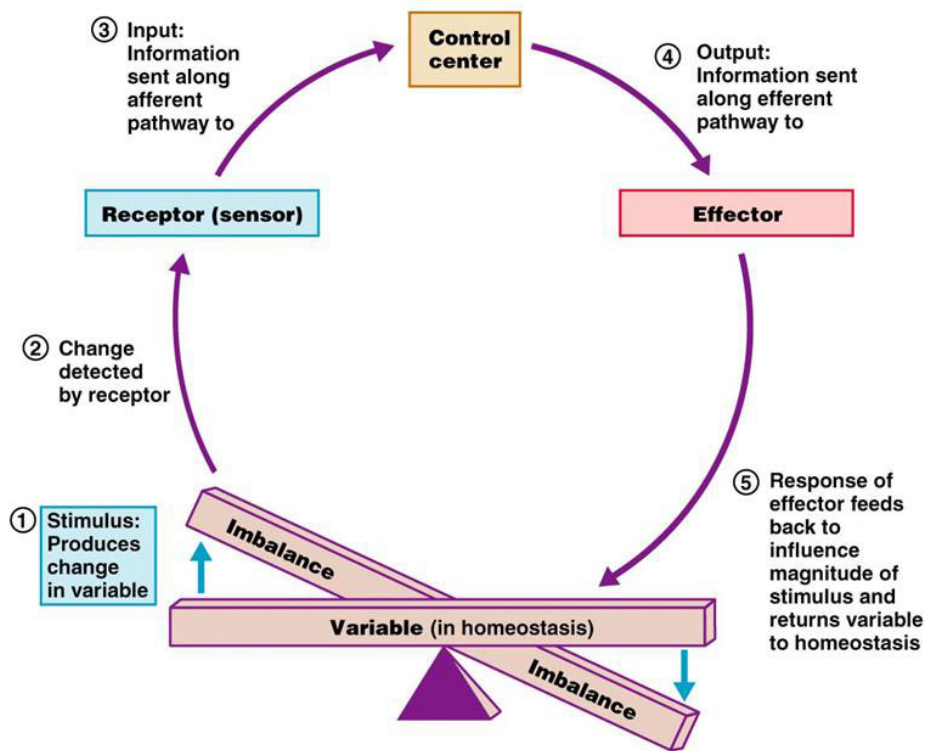


Fig 61. Interactions among the elements of a homeostatic control system maintain stable internal conditions by using positive and negative feedback mechanisms.

Stimulus - produces a change to a variable, more specifically the factor that's being regulated

Receptor - detects the change of a variable. The receptor must respond to changes in the environment, also called stimuli, and continuously monitor the environment.

Input – information travels through the afferent pathway to the control center which determines the appropriate response and actions that need to be taken

Output – the information sent from the control center travels back the afferent pathway to the effector

Response – the response from the effector has the purpose of balancing out the original stimulus and maintain homeostasis

Using positive and negative feedback mechanisms the elements of the homeostatic control system interact with each other to maintain constant a stable internal condition.

An example of negative feedback mechanism is a heating system or thermostat. When the thermometer in the thermostat, which plays the role of a receptor, detects temperatures lower than the ones that were set the heating system is turned on, if the temperature go above the set

temperature then the thermostat turns off the heating system in order to maintain the ideal temperature. [31]

Another good example of negative feedback mechanism is how the body controls the blood glucose level by using insulin (Fig 62). When the blood glucose levels rise the receptors in the body detect the change so that the control center, in this case the pancreas, starts secreting insulin so that the glucose in the blood gets absorbed by the body thus decreasing the blood glucose levels. When the blood sugar level reaches homeostasis the insulin secretion stops.

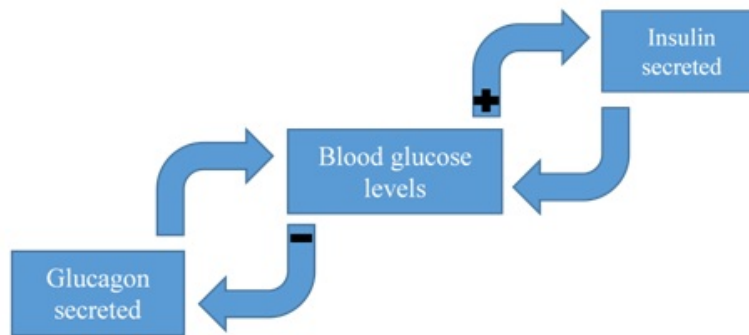


Fig 62. Blood sugar regulation

A positive feedback mechanism is the exact opposite. In the case of negative feedback the output will reduce the original effect of the stimulus, but in a positive feedback mechanism the output will enhance the original stimulus. Child birth is a good positive feedback system example. While in labor the hormone called oxytocin is being release so that contractions intensify and speed up. The increase in contractions trigger the release of even more oxytocin until the baby is born. When the birth is finished the release of oxytocin stops and so does the positive feedback mechanism.

Blood clotting is another good example for positive feedback mechanism. When a vessel gets damages platelets start clinging to the injured site and release chemicals that cause even more platelets to be attracted. The signaling chemicals continue to be released by platelets until the injury is covered and a clot is formed.

A positive feedback mechanism will enhance the original stimulus while a negative one will inhibit it, so the key difference between the two is their response to change. Positive feedback amplifies change while negative feedback reduces change. That means that the positive feedback mechanism will result in a higher production and more products, more contractions, more clotting plateles, etc, while negative feedback mechanism will result in decrease of production and less product, less sugar, less pressure, less heat, etc. The positive feedback

mechanism moves away from a targeted point while negative feedback mechanisms moves towards the targeted point.

## 5.7 General Components Flow

The components of the Integrated Decision Making Environment work together to form a coherent and unified decision making environment. Just like the components of a car, each component of the Integrated Decision Making Environment can very well work independently and provide a specific function relevant to the decision making process, but when they work together the synergy becomes obvious. Just like a car provides additional functionality that can't be found when the components are used independently, so does the Integrated Decision Making Environment starts to feel like a real organism that automatically regulates itself to better cope with the external and internal environment with the help of the deciding agents that act within the roles they are given by the organism they live in.

### A. Profile

- Users create their account or can login using Facebook Login/ GooglePlus/ Twitter/ Yahoo/ etc, and validate it using national ID
- The Profile Page will consist of a simple social network that will only have vital social functionality like, message friends, post pictures, post short statuses (like twitter, 140 characters at most)
- Users at first start out with Trust Level 1, they can use their Profile page to attract friends to give them a vote of trust. Users will be guided to express their political views, social views, economical views etc.
- The Trust level will be used everywhere around the website to create a natural hierarchy.
- Each user can give their vote of trust to anyone else(once per person) and they can receive votes from anyone else(one vote from each).

### B. Feed (*Organic Development + News*)

- On the Feed page users can view different news articles or personal issues were organically submitted by individual users.
- If an article stands out by being Up Voted by many and the article refers to an issue the person is experiencing, it can be promoted to become an Issue and will be shown in the Issue List page. On the issue List page we can have filters that can filter only issues from friends, or only issues from your country, or only issues in a specific category. Also all Issues will have tags attached to them, tags will be used to better match similar issues and will also be important for the reports page.

### *C. Issues*

- If a person is interested in an issue it can upvote/follow that issue.
- The Issues page shows Framed Issues that were identified in the Feed page coming from the governed body (institution, department, state, etc).
- In Community Organizing users can organize themselves in order to get support from Social Groups to come up with solutions to the issues at hand.

### *D. Organize*

- In Community Organizing users will be able to organize Campaigns of different types: meetings, rallies, email/fax/phone campaigns
- The Community Organizing tab will provide the means for users to have their problems heard and attract the people that can solve the problems.
- In the Community Organizing we will allow users to add their own Campaign Methods on top of the ones we will have by default (to increase people's creativity in protesting peacefully – like all people wearing a shirt with a specific message, call the parents of the person that is creating the issue and so on) and we will promote only Non Violent forms of Protest. We will add a protest etiquette that people can read before starting any Campaign.

### *E. Policies, Execution and Disputes: Policy Creation, Live Issues, Executive groups, Legislative group, Judicial Groups, My Groups.*

- Each Framed issue becomes the center of attention for Social Groups, these social groups represent people interested in helping out with Policy Creation for the Categories/Domains they are interested in. We can have cases where a person joins all groups or when a user doesn't join any group but he gives the vote of trust to someone else to represent them.
- Each Social Group has a calculated Trust Level based on the users that make up the group.
- Anyone can create a social group if he thinks he has a new unique view of things that can help others that also that have similar interests and activities.
- Social Groups can also act as a syndicate for different roles people can play in society.
- Once you are part of a Social Group, or you created your own, you can take part in Policy
- Creation and you can increase your influence by promoting valuable Policies for people in different social/economical/political contexts.
- Users of groups can have different roles within the group like: owner, manager, activist, etc
- The owner has the option to promote other users to managers in their groups.
- There can be Social groups that require an Invitation, some will be free to join, others will require approval.
- Policy Making will enable users to find solutions for everyday problems in an organized and collaborative way.

- In the Live Issues Tab, we will have the Framed Issues the person is following. If he is part of a Social Group, he can initiate a Policy for any Issue.
- The Policy will be built inside the Social Group but will also be visible publicly and people can comment on them.
- Once Policy receives the required number of votes and provides the best solution for the problem (that will be decided in the Issue Framing Tab when the issue is defined).
- We can have a democratic vote as default, where all people that follow that issue get to vote.
- Once an issue is voted up it will become an active Policy of that Nation.
- All Nation Policies/Laws will be shown in Active Policies Page that will be created for each Nation or Organization. Users will have the possibility to browse through the Policies and request changes by Framing an Issue.

## 6. Use Cases for the Integrated Decision Making Environment

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The Integrated Decision Making environment can be used in any kind of social organization, institution, corporation or company. In this chapter we will present two examples of how the decision making environment can be used.

### 6.1 University Use Case

In order to fully migrate the management system of a University to using the Integrated Decision Making Environment we go through each step and describe the operations that need to take place. For the sake of simplicity we will limit our case study to only the general management of the University and not drill down into each individual Faculty Management structures.

**Step 1: Identify each of the current hierarchical management structures and the roles they contain**

#### University administrative structure

A University is organized in faculties. The main administrative council that governs the whole University is made up of one Rector, three Prorectors, one DUSC Director and one General Administrative Director.

#### University administrative structure roles

The administrative, executive and judicial roles will have to integrate the following existing roles:

**The Rector**, which is a role that combines executive, legislative and judicial powers. The rector should be elected based on direct votes from other University members. The role of Rector should be assigned to the University member that has the most votes of trust/

**The Prorector**, is the second role in terms of responsibility in the classic University administrative structure. In this Case study we will be having 3 Prorectors. The Prorector role is also going to be assigned based on the amount of votes of trust, the members with highest votes of trust have the first option in choosing this role. Using the three branches of governance pattern we can give each of the three members that take the Prorector position, based on their skills, the legislative, executive and judiciary function will be assigned to them.



**DUSC Director** role is the head of the Doctoral University Studies Counsel (DUSC) and it's similar to the Rector role. The CSUD Director coordinates the legislative, executive and judicial branches inside the DUSC department and represents the department as a whole.

**General Administrative Director**

The General Administrative Director role can be used as the second in command of the executive branch, in tandem with the Prorector assigned as head of the executive branch.

**Step 2: Design the horizontal and vertical governance structures**

In order to facilitate the migration of the existing roles (Fig 63) to a format compatible with the recommendations of the Integrated Decision Making Environment governance structure we created a simple design that used a convergent governance model together with the the three branches of governance.

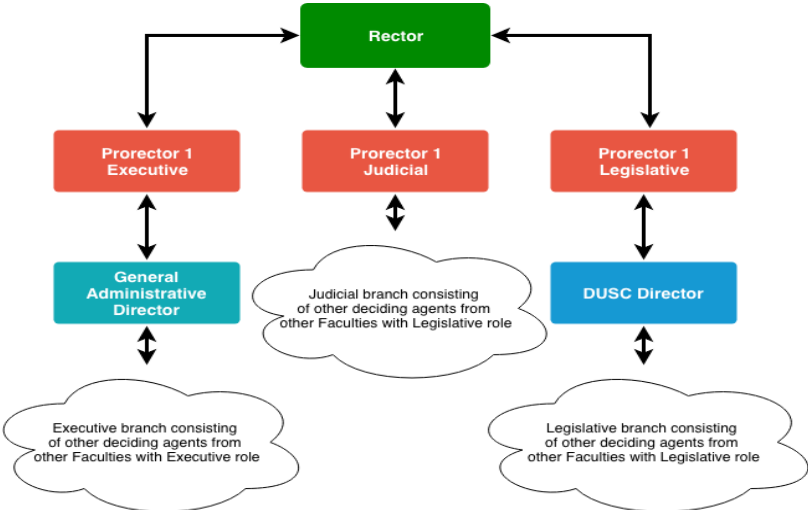


Fig 63. Existing University Management Roles

**Step 3: Set up initial Blockchain**

After we have the initial governance structure with all the roles we will need to set up the first Decision Blockchain Node which will act as a distributed Database for the Integrated Decision Making Environment.

The next step is to initialize the streams that enable the decision blockchain be used as a general purpose append-only database. The blockchain will provide timestamping, immutability and notarization. A blockchain that contains multiple streams is called a MultiChain blockchain and can contain any number of streams, where the data published in every stream is stored by every node.

In our particular case we will need to create the following streams:

Members stream - which will contain each member of the Institution and their public key, which was generated by the ID they provide, the public key can be changed by either the member himself or by a designated department that is given authority over member registration and management.

Decision Stream, Votes stream, Resource Stream and Legislative stream will start off completely empty and blocks will be created using the Integrated Decision Making Environment based on the activity of the members that can push signed blocks to each of these streams using their public keys.

The Definitions Streams will need to be configured with the necessary data and will act as a foundation to how the decision making and governance process will unfold. Inside the Definition Stream we will have the primitive definition blocks, defining the member roles, member permissions, votes and member count prerequisites relative to member count, and the governance structure, in our case a three branched convergent governance structure, with the Rector in the role of president and general inside and outside representative of the University.

#### **Step 4: Add all resources to the Resource Stream**

After the MultiChain streams were initialized and initial definitions were added we continue by adding all the resources the University has. The resources will be managed using the Universal Resource Management and Logistic component that uses the blockchain.

In our case we will add as resource all real estate the University has, all technical resources at its disposal, the state budget allocated to the University, as well as any Intellectual Property that the University possesses.

#### **Step 5: Create the role definitions on the blockchain**

In this step we will get the initial governance structure design and create the necessary blocks inside the Definitions Stream so that we have all the necessary roles to implement the governance structure.

As we mentioned earlier we will have the following roles:

**The Rector**, which we will define as the member with most votes of trust and who is in charge of representing the University as a whole both on the inside and on the outside.

**The Prorector** role will require only partial responsibility as it will be attached to one of the three branches, Legislative, Executive or Judicial.

**DUSC Director** and **General Administrative Director** roles, together with two Prorectors constitute the top management of the Legislative and Executive branches that unfold into all the departments of the University and make up the Vertical Hierarchical Governance Structure.

#### **Step 6: Manually allocate the existing roles to members**

After the roles are defined and all existing managing members of the institutions are added to the Members Stream we start allocating the roles to them. In this step, because we don't have access to the Ranked organic Hierarchy created by the votes of trust we just allocate the roles manually. The initial role allocation should be kept in place for a few months until at least 50% of the managing members use their vote of trust, to either promote themselves or promote someone else.

#### **Step 7: Provide each member in the governed body an account which is linked to his ID and stored on the blockchain**

After the governance structure is in place and all roles are allocated we can start adding member accounts to all people that make up the governed body, in our case they will be faculty staff, teachers and of course students.

Whenever a new member is added the blockchain transaction needs to be signed by the member management department, which will be put in place and given its authority by the top level management made up of the Rector, Prorectors and two directors. In order for a Member Management Department to have authority over adding members it must be supported by at least a certain threshold of votes of trust coming from the top managing group.

Each new member will have their data stored on the blockchain as well as a public key that was generated for each of them. All transactions like voting, resource management, issue framing, pushing legislature or executive orders will need to have a corresponding block that's signed by at least one member, which is considered the owner or founder of that block. Once the transaction is approved it will become active and the owner member won't be able to alter it because it will be placed under the authority of the department or institution as a whole and that

block can only be changed if an issue is created and enough votes of trust are gathered in favor of changing it.

### **Step 8: Move all all decision making and management to the Integrated Decision Making Environment**

After all the members have access to their account and the initial constitution of the University is in place we can start using the Integrated Decision Making Environment to interact with the system as a whole and make changes to it. The migration to the new system can be made incrementally, starting from the top up and bottom down. Students can start using the Issue Framing component to signal and aggregate issues or propose improvements, while the top managing committee made of the Rector and Prorectors can use it to adjust the laws and executive methodologies used inside the Institution such that the issues that come up will be resolved.

## **6.2 Crypto Currency Investment Use Case**

For picking a viable altcoin to invest in we can create a simple Bayesian Network based on 2 factors: creator trustworthiness and altcoin popularity. The final probability of an altcoin to be profitable is influenced by both altcoin popularity and creator trustworthiness. Also the chance of a creator to be trusted depends on the altcoin being popular or not.

For our simple BN we can identify two events which could cause an : either the altcoin is popular or the creator is trusted. Also, suppose that the altcoin popularity has a direct effect on the trustworthiness of the creator(namely that the altcoin is popular , the creator is usually trusted). Then the situation can be modeled with a Bayesian network.

To understand how this is similar to a swarm of bees making a decision we can consider the group to be the swarm of bees and each individual in the group is a worker bee that proposes different location alternatives to harvest next. In our example the alternatives we must choose from, which are the equivalent of harvest locations, are the altcoins we want to invest in that will bring the most profit over a specific period of time.

As we know a worker bee signals other bees about the alternative they are proposing using a special dance, but in the case of human decision making, dancing isn't very relevant in determining the best solution in most cases, so we must use the human equivalent of a bee dance. For human decision making we use the trust rank which is calculated based on the votes of trust an individual has. In order to understand the relevance of the vote of trust and why we

consider it the natural alternative to a bee’s dance we must look at someone’s life as a continuous dance and the way someone lives their life can be trustworthy or not and they get recognition through the votes of trust they receive from others. In our example each altcoin, represented through a flower, is the equivalent of a harvest location that the bees must choose from. We know that a bee swarm always acts as one cohesive group, so once a decision is made each member of the group will act according to it. [12] Each member of the human swarm can influence the final decision by adding their own factors and the probability of each factor, which represents the personal belief of that member about how much that factor influences whether or not the altcoin will be profitable.

All three variables have two possible values, T (for true) and F (for false).

The joint probability function is:

$$P(Pr, Tr, Po) = P(Pr|Tr, Po)P(Tr|Po)P(Po)$$

where the names of the variables have been abbreviated to Pr = Altcoin is profitable (true/false), Po = The altcoin is popular (true/false), and Tr = The creator is trusted (true/false).

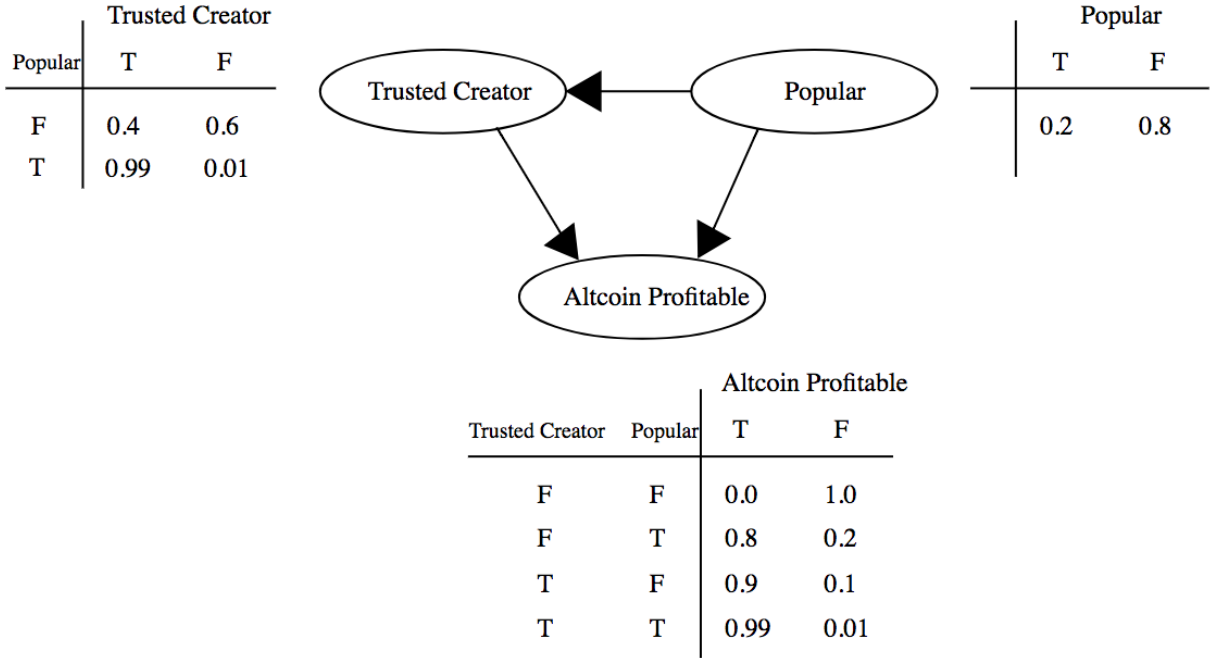


Fig 62. Bayesian Network for picking altcoin to invest in, based on 2 factors

The model (Fig 62) can answer questions like "What is the probability that the altcoin is popular, given that the altcoin is profitable?" by using the conditional probability formula and summing over all nuisance variables:

$$P(Po = T|Pr = T) = \frac{P(Pr = T, Po = T)}{P(Pr = T)} = \frac{\sum_{Tr \in \{T, F\}} P(Pr = T, Tr, Po = T)}{\sum_{Tr, Po \in \{T, F\}} P(Pr = T, Tr, Po)}$$

Using the expansion for the joint probability function  $P(Pr, Tr, Po)$  and the conditional probabilities from the conditional probability tables (CPTs) stated in the diagram, one can evaluate each term in the sums in the numerator and denominator.

$$\begin{aligned} P(Pr = T, Tr = T, Po = T) &= P(Pr = T|Tr = T, Po = T)P(Tr = T|Po = T)P(Po = T) \\ &= 0.99 \times 0.01 \times 0.2 \\ &= 0.00198 \end{aligned}$$

Then the numerical results (subscripted by the associated variable values) are:

$$P(Po = T|Pr = T) = \frac{0.00198_{TTT} + 0.1584_{TFT}}{0.00198_{TTT} + 0.288_{TTF} + 0.1584_{TFT} + 0.0_{TFF}} = \frac{891}{2491} \approx 35.77\%$$

### Steps for using the Bayesian network for decision support integrating the trust rank

Given the Bayesian methods described above we can define the steps that must be taken to allow the group to converge on a single final decision:

- Any member of the group can introduce any number of solutions or alternatives that make up the solution space. In our case each solution would represent an altcoin: Ether, Ripple, Litecoin, etc
- An introduced solution can either be stand-alone, without depending on any other factor that influences it's profitability, with a single associated belief that represents the probability of success of that altcoin, or dependent on a set of factors, also introduced by the member, that we use inside the Bayes theorem to calculate the probability of success of that solution.
- Each factor will have a weight which represents the amount of influence it will have on the final probability of success of the solution it's associated to. For our example when calculating the profitability of an altcoin the creator factor can have a 20% weight over the final profitability probability. So if we start all altcoins with 50% chance of being profitable and the weight of the creator variable is 20% and we believe that a certain

creator is trustworthy, thus positively influencing the profitability of an altcoin, then the final probability of that altcoin to be profitable will be 70%

- To easily evaluate each alternative, using the factors associated with a proposed solution, we generate a bayesian network that calculates the final probability of that solution also integrating the member's trust rank.
- After we factor in the trust rank we will get a list of solutions ordered by probability of success from which we can choose are final solution.
- In order to reach a consensus on the final solution, once we reach a critical mass of involved members (more than 50%), we take the top 5 proposed solutions based on their probability of success, starting from the bottom up, and we vote on them. Using this method we give an equal chance to all proposed solutions that reach the top 5 to be selected. Because solutions are removed one by one from the bottom up all the support that the removed solutions had from members can migrate to other remaining solutions, not necessarily the top one.
- Members of the group that have a higher rank of trust will weight in more on the final vote but if their proposed solution didn't make it in the top 5 their voting power will be distributed to the remaining solutions

In order to properly understand why a Bayesian Network integrating the trust rank is the best solution for modelling swarm like decision making we will start with a relevant example that has many real-life use cases: deciding which altcoin our group should pick to invest in next. Altcoins are the alternative cryptocurrencies launched after the success of Bitcoin

Following the initial example of choosing an altcoin for investing we have to define the members of the group and their trust rank.

We can consider the group has 5 members, M1, M2, M3, M4, M5 and each of them have the following number of votes of trust:

M1 = 0 votes - 0%

M2 = 0 vote - 0%

M3 = 1 vote - 20%

M4 = 2 votes - 40%

M5 = 2 vote - 40%

Each of the members come up with a proposed solution in the form of a altcoin: M1 chooses Monero, M2 chooses Ripple, M3 chooses Litecoin, M4 chooses Bitcoin Cash and M5 chooses Ether.

Each member inputs the probability, based on their beliefs, that their altcoin is going to be profitable.

Monero (proposed by M1) = 60%, Ripple(proposed by M2) = 70%, Litecoin(proposed by M3) = 80%, Bitcoin Cash(proposed by M4) = 80%, Ether(proposed by M5) = 90%

Some probabilities of profitability are calculated using additional factors using a Bayesian Network.

In the case of Ether and Litecoin we have 2 factors: creator trust and popularity so the final probability of them being profitable is calculated using the Bayesian Network Inference formula.

We create the final list of alternatives the members can select from by combining the trust rating of the member that proposed the altcoin and the probability of it being profitable, and we choose the first three.

So we will have:

1. Ether =  $0.4 \times 0.9 = 36\%$  (chance of success)
2. Bitcoin Cash =  $0.4 \times 0.8 = 32\%$  (chance of success)
3. Litecoin =  $0.2 \times 0.8 = 16\%$  (chance of success)

Now we can begin the final voting step where we start from the bottom position and vote our way up until we get a majority.

After the first vote for the Litecoin we get only 20% approval, so we continue with the next altcoin.

When we vote for the Bitcoin Cash we have 2 possibilities:

- All Litecoin votes go to voting for the Bitcoin Cash, in which case we will have 60% approval and the Bitcoin Cash will become the next altcoin the group invests in.
- The Litecoin voters, in this case only member M3 (but there can be a lot more in real life situations) vote against Bitcoin Cash in order to hold their votes for the next altcoin on the list. In this we get to the first position in the list of selected alternatives so by default we reach consensus (Fig 63) and the next altcoin the group invests in is the Ether



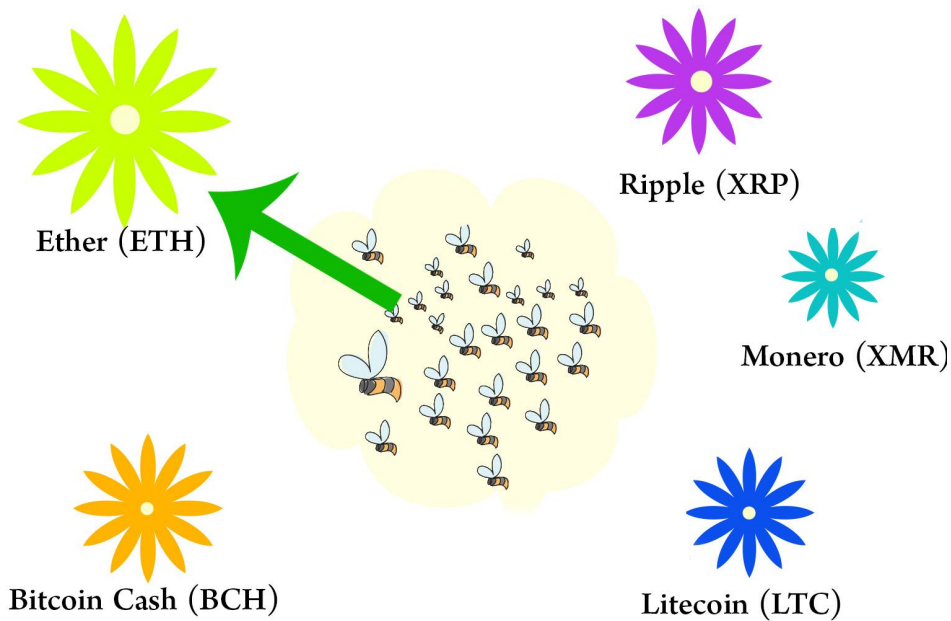


Fig 63. The swarm reaches consensus and decides on Ether to be the next altcoin to invest in. The Integrated Decision Making Environment was applied on a small scale inside an investment company with the purpose of identifying the best opportunities for investment in the cryptocurrency market.



Fig 64. Coinmarketcap graphs for Ethereum and Ripple during the time of investment

As each of the deciding agent was knowledgeable regarding many aspects of what makes a crypto currency successful the platform allowed for a very precise identification of the currencies that were considered most promising. It turned out the prediction was correct so that the company achieved a very high return on investment and the chosen coins currently have some of the highest overall market cap. We can showcase the evolution of two of the coins that were chosen: Ethereum and Ripple (Fig 64).

## 7. Conclusions

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During the research phase of this thesis I have experimented with human consciousness, psychology and epigenetic techniques. As a proof of concept for the validity of the conclusions I reached, I managed to heal the symptoms of my chronic genetic illness (which I was born with) Cystic Fibrosis. Genetic code is activated/deactivated by beliefs/logical patterns that are stored in the form of physical neural connections, neural circuits and neural pathways. These genetic switches are triggered by both the mental environment of a person but also by external social environment factors, so any improvements that can be applied to either of the two will enhance the overall quality of life.

As we observed in all natural systems that involve decision making our integrated decision making environment should enable all the participants to negotiate in synchrony, adapting decisions emerging before them in real-time.

Deciding agents don't express static views, but continually assess and reassess their own unique convictions with respect to each of the possible outcomes, weighing their personal confidence and preferences. With all participants doing this in parallel, the body of governance can quickly converge on solutions that reflect the collective will of the group. This is why swarms [9][11] are able to efficiently capture a group's collective wisdom.

Another important characteristic of any decision making system is its capability to adapt to the needs of the group using it and to the environment it's being used in. For that purpose, the Integrated Decision Making platform integrates a configuration component using a blockchain JSON settings object that allows us to fine tune the platform as well as enable and disable its features, in resemblance to the human Epigenome.

Using an organically coherent system of governance emergent from the natural fractal [1][3] expressed in the anatomy of the human body, such as the Organic Integrated Decision Making Environment we are proposing, will align the human race to its full evolutionary potential, both at a personal and social level. In order to achieve this, we need to gather, classify and act upon any good ideas that can arise in anyone's mind, not just a few that are in power at a certain time, like the previous, prone to corruption, systems.

Because we now possess the technology to recreate our body's perfect governing system it's only natural we implement it and start using it, and in doing so remove all possibility of corruption to ever take part in the governing process like it happened so many times in the past.

By implementing a decision-making system that's specifically designed for us by nature itself, and use it in fields such as social governance, we take the responsibility from any small governing group of people and distribute it to each and every one of us, in accordance to our individual capabilities and predispositions.

Some of the most profound personal conclusions I reached during my research are: [1]

- the nature of God as being physical wisdom and love that transcends time
- nature has all the answers built-in, for those that can see them
- there are no coincidences, the order within can be observed in the order without
- technology modeling natural anatomical mechanisms present in the human body already exists in partial form as online platforms like Wikipedia, Facebook, Reddit, etc, which will be included in my final application for the Online Social Governance
- human consciousness transcends and controls its physical state
- neural connections are like tools or containers that the evolutionary forces of nature uses to help us make sense of what we already know and guide us in the direction we want to go
- emotions we create come back to us to create a feedback loop, with the purpose of identifying the neural connections that made them possible
- consciousness works like an operating system
- the nature of evil can be translated into a deterministic psychological structure maintained by faulty neural connections created over our individual evolution
- our brain takes part in influencing the collective consciousness and our ideas spread around the the planet like an impulse is broadcasted over a network
- all information is relevant once the truth is found and information processing is going to be one of the most important fields of study in the future
- the heterogeneity of life is perfected once each individual is connected with his built in purpose and finds meaning in his life.
- humans encouraged to live and express their individuality will resemble puzzle

pieces that will perfectly fit together, without glue holding them together, in contrast with a conformist philosophy which creates bricks out of people and holds them together using concrete (see Pink Floyd - Another Brick in the Wall)

- music is the answer

## **Contributions**

This thesis describes only some of the most fundamental components that should make up an integrated decision making environment, we believe the solutions biology and organic system offers us are well suited and adequate for decision making and as the organic and conscious fractal of reality, that we are part of, unfolds and further describes itself to us, we will be able to learn and integrate new dimensions and functions into our decision making environment.

Some of the personal contributions that this thesis brings are:

- Adapting Blockchain technology to be used as a Decision Blockchain, thus mimicking the functionality of the human DNA and all its advantages
- Defining the Feedback component, which is an analogue for the Organic Homeostatic Function found in biological organisms that allows them to self regulate through feedback loops
- Designing an intuitive interface and describing a possible implementation for the Organic Developments and Issue Framing Component that mimics the functionality of nerve cells, nervous ganglions and spinal cord and describing.
- Creating a configuration protocol for the Decision Blockchain that would act as epigenetic flags, which enables high degrees of flexibility and adaptability for the Integrated Decision Making Environment
- Finding a modern approach to the idea of weighed votes through the Trust Rank Component that allows for organic hierarchies to be created dynamically and by doing so mimicking the prioritization and differentiated authority naturally found in biological organisms, more specific when it comes to their internal organs or cells of different types. For example the brain has a higher priority when in a state of danger than the hands or feet, thus the natural instinct to protect your head when you fall. Also when in a state of stress the Cortisol hormone decreases insulin sensitivity to most types of body cells so that the brain cells will have access to more energy in the form of glucose (thus the sugar level spikes when stressed).

- Adapting existing prioritization algorithms, like Reddit Hot or Confidence Algorithm, to use the user trust rank, thus enabling a faster and more reliable way of identifying and solving problems
- Defining a simple and generic architecture for the Integrated Decision Making Environment that combines the blockchain as data source and relies on micro-services based components to provide a modularized solution that integrates different yet complementary components into one unitary and coherent system

### **Future Research and Development**

The results and research done for this thesis only scratch the surface of how an organic Decision Making Platform can be designed and used. There are a lot of natural patterns, organisms and phenomena that can be further analyzed to identify other components that could prove to be even more crucial to the overall process of decision making and provide greater levels of coherence and insight on how the human society is suppose to govern itself. Some of the domains worth researching are:

Music - an important domain that would bring a lot of progress in understanding humanity and what makes us tick is music. Music can be studied in combination with psychology and neuroscience. It's interesting how music establishes a generic harmonic protocol so that people gather around it despite their differences. We know people go to concerts in great numbers even though their life views and beliefs might be in complete contradiction.

Religion – even though currently religion is one of the major factors that generates conflict, understanding all ancient writings, mythologies and religions from a teleological (study of meaning or purpose) perspective combined with the study of archetypes can provide some deep insight on the primitives of the human character and the natural drives that are at the base of human consciousness, allowing us to create unique and personal interfaces that will mitigate all inner and outer conflict so that individuals will be able to interact with the decision making environment in a constructive and meaningful way, eliminating the feeling of not being understood.

Astronomy - the study of astronomy from a perspective relevant to human decision making and governance will also return important results.

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## 8. Bibliography

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- [1] M. A. Manolache, "Organic Integrated Decision Making Platform, Swarm Intelligence Using Blockchain Technology," *Advanced Topics in Optoelectronics Microelectronics and Nanoelectronics*, December 2018.
- [2] M. A. Manolache, "Integrated Decision Making Platform," *21st International Conference on Control Systems and Computer Science*, 2017.
- [3] M. A. Manolache, "Integrated Decision Making Platform - Frontend Components Built on top of the Decision Blockchain," *Bulletin of the Polytechnic Institute Iasi*, 2018.
- [4] M. A. Manolache, "Multilayered Integrated Decision Making Platform Architecture," *The Scientific Bulletin by University POLITEHNICA of Bucharest*, 2019.
- [5] L. Rosenberg, N. Pescetelli and G. Willcox, "Artificial Swarm Intelligence amplifies accuracy when predicting financial markets," *Electronics and Mobile Communication Conference (UEMCON)* , 2017.
- [6] W. Premchaiswadi and N. Jongsawat, Group Decision Making Using Bayesian Network Inference with Qualitative Expert Knowledge, Bayesian Network., 2010.
- [7] L. B. Rosenber, "Human Swarming, a real-time method for Parallel Distributed Intelligence," *Swarm/Human Blended Intelligence Workshop*, 2015.
- [8] M. A. Manolache and N. Tapus, "Integrated Decision Making using the Blockchain," *The 7th International Conference On Information Technology And Quantitative Management*, 2019.
- [9] F. A. Hayek, *The Use of Knowledge in Society*, 1945.
- [10] N. J. Foss, *The Knowledge Governance Approach*, 2005.
- [11] F. G. Filip, *Sisteme suport pentru decizii*, Ed TEHNICA, 2007.
- [12] I. Ben-Gal, "Bayesian Networks," 2008. [Online]. Available: <https://onlinelibrary.wiley.com/doi/full/10.1002/9780470061572.eqr089>.

- [13] "What is a fractal," 2018. [Online]. Available: <https://fractalfoundation.org/fractivities/WhatIsaFractal-1pager.pdf>.
- [14] "Blockchain: smart contract benefits and vulnerabilities," 2018. [Online]. Available: <https://medium.com/swlh/blockchain-smart-contract-benefits-and-vulnerabilities-7543b3955ac9>.
- [15] "Getting to know smart contracts," 2018. [Online]. Available: <https://www.leadmark.nl/getting-to-know-smart-contracts/>.
- [16] "How reddit ranking algorithms works," 2018. [Online]. Available: <https://medium.com/hacking-and-gonzo/how-reddit-ranking-algorithms-work-ef111e33d0d9>.
- [17] "Reddit ranking system," 2017. [Online]. Available: <http://amix.dk/blog/post/19588>.
- [18] "The Mathematics of Reddit," 2017. [Online]. Available: <http://scienceblogs.com/builtonfacts/2013/01/16/the-mathematics-of-reddit-rankings-or-how-upvotes-are-time-travel>.
- [19] F. Ehram, "Blockchain Governance: Programming Our Future," 2017. [Online]. Available: <https://medium.com/@FEhram/blockchain-governance-programming-our-future-c3bfe30f2d74>.
- [20] G. Little, Programming with Human Computation, Massachusetts, 2011.
- [21] T. D. Seeley, "Stop signals provide cross inhibition in collective decision-making by honeybee swarms," *Science*, no. 335.6064, 2012.
- [22] T. Seeley, D. Visscher and P. Kirk, "Choosing a home: How the scouts in a honey bee swarm perceive the completion of their group decision making," *Behavioral Ecology and Sociobiology* 54, no. 5, pp. 511-520.
- [23] B. Science, "Organs - Brain," 2017. [Online]. Available: <https://www.bbc.co.uk/science/humanbody/body/factfiles/brain/brain.shtml>.
- [24] "What is a Neuron?," 2017. [Online]. Available: <https://sciencebeta.com/neuron/>.
- [25] "Corpus Callosum and Brain Function," 2017. [Online]. Available: <https://www.thoughtco.com/corpus-callosum-anatomy-373219>.



- [26] A. Vamshi, "Management Concepts Business Ethics," 2011. [Online]. Available: [https://www.academia.edu/28572641/Management\\_Concepts\\_Business\\_Ethics](https://www.academia.edu/28572641/Management_Concepts_Business_Ethics).
- [27] N. Tapus and M. A. Manolache, "Universal Resource Management and Logistics Using Blockchain Technology," *22nd International Conference on Control Systems and Computer Science*, 2019.
- [28] Saurav Chakraborty, Kaushik Dutta and D. J. Berndt, "Blockchain based Resource Management System,," 2017.
- [29] "MultiChain Platform," 2018. [Online]. Available: <https://en.bitcoinwiki.org/wiki/Multichain>.
- [30] "Bitcoinwiki," 2018. [Online]. Available: <https://en.bitcoinwiki.org/wiki/Multichain>.
- [31] "Homeostasis: positive/negative feedback mechanisms," 2018. [Online]. Available: <https://anatomyandphysiologyi.com/homeostasis-positivenegative-feedback-mechanisms>.
- [32] A. Aaltonen and G. F. Lanzara, Building Governance Capability in Online Social Production: Insights from Wikipedia, *Organization Studies* 36, no. 12, 2015.
- [33] R. A. Abualsamh, B. Carlin and R. R. McDaniel, Problem structuring heuristics in strategic decision making. *Organizational Behavior and Human Decision Processes*, 1990.
- [34] E. Chi, B. A. Pendleton, B. Suh and T. Mytkowicz, Power of the Few vs. Wisdom of the Crowd: Wikipedia and the Rise of the Bourgeoisie, University of California, 2005.
- [35] L. Buriol, C. Castillo, D. Donato, S. Leonardi and S. Millozzi, Temporal Evolution of the Wikigraph, Hong Kong, 2006.
- [36] M. Haller and M. Hadle, "Happiness as an Expression of Freedom and Self-Determination," 2004.
- [37] K. Passino, T. Seeley and P. Visscher, "Swarm Cognition in honeybees," *Behav. Ecol. Sociobiol.*, no. 62, 401, 2008.

- [38] J. Marchall, R. Bogacz, A. Dornhaus, R. Planque, T. Kovacs and N. Franks, "On optimal decision making in brains and social insect colonies," *J.R. Soc Interface*, no. 6, 1065, 2009.
- [39] I. Couzin, "Collective Cognition in Animal Groups," *Trends Cogn. Sci*, no. 13, 65, 2008.
- [40] B. B. Mandelbrot, *The fractal geometry of nature.*, Macmillan, 1983.
- [41] J.-F. Gouyet, *Physics and fractal structures*, Paris/New York: Masson Springer, 1996.
- [42] R. A. Abualsamh, B. Carlin and R. R. J. McDaniel, Problem structuring heuristics in strategic decision making, *Organizational Behavior and Human Decision Processes*, 1990, pp. 159-174.
- [43] E. Chi, B. A. Pendleton, B. Suh and T. Mytkowicz, "Power of the Few vs. Wisdom of the Crowd: Wikipedia and the Rise of the Bourgeoisie," *Aniket Kittur University of California*, June 2005.
- [44] J. Surowiecki, "The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business," *Economies, Societies and Nations*, 2004.
- [45] F. G. Filip, "System analysis and expert systems techniques for operative decision making," *Computational Systems Analysis: Topics and Trends*, ELSEVIER, 1992.
- [46] F. G. Filip, Z. C. B. and C. Ciurea, *Computer- Supported Collaborative Decision Making*, Springer International Publishing , 2017.
- [47] S. S.P., G. Deutsch and W. Freeman, *Left brain, right brain*, New York, 1998.
- [48] P. L. L. I. Wagner T.D., "Valence, gender, and lateralization of functional brain anatomy in emotion: a meta-analysis of findings from neuroimaging," *NeuroImage 19*, 2003.
- [49] S. C. A. Y. D. Zalewski L. J., "Using Cerebral Dominance for Educational Programs," *The Journal of General Psychology 119*, 1992.
- [50] F. a. p. a. D. 2010, 2017. [Online]. Available: <http://www.devoxx.com>.
- [51] E. Cell, 2018. [Online]. Available: <http://www.bio.davidson.edu/bernd/Lab/EpithelialInfoWeb/index.html>.

- [52] P. a. N. F. L. i. Biology, 2018. [Online]. Available: <https://www.albert.io/blog/positive-negative-feedback-loops-biology>.
- [53] "Wikimedia servers," 2018. [Online]. Available: [https://meta.wikimedia.org/wiki/Wikimedia\\_servers](https://meta.wikimedia.org/wiki/Wikimedia_servers).
- [54] "Who has the most Web Servers?," 2017. [Online]. Available: <http://www.datacenterknowledge.com>.
- [55] "How Not To Sort By Average Rating," 2018. [Online]. Available: <http://www.evanmiller.org/how-not-to-sort-by-average-rating.html>.
- [56] "Open Compute Project," 2017. [Online]. Available: <http://opencompute.org>.
- [57] Wikipedia, "Group Decision Making," [Online]. Available: [https://en.wikipedia.org/wiki/Group\\_decision-making](https://en.wikipedia.org/wiki/Group_decision-making).