The Cognitive Blockchain: A Theoretical Approach Towards Removing the Barriers to Blockchain Scalability and Deployment

Andy E. Williams, Nobeah Foundation, Nairobi, Kenya

Abstract
This paper explores a theoretical approach based on the newly emerging science of General Collective Intelligence (GCI) which suggests that the concept of a "cognitive blockchain" can reliably create the capacity to exponentially increase the scalablity, decentralization, security, and any other architectural service level characteristics of blockchain platforms simultaneously. This paper also explores why the cognitive blockchain is suggested to have the potential to exponentially increase the use of blockchain technology and the market capitalization of blockchain based cryptocurrencies.

Keywords
General Collective Intelligence; Artificial General Intelligence; intelligent agent; cognitive blockchain; scalability; security; decentralization

Introduction

A number of solutions have been proposed in response to the blockchain trilemma conceptualized by Ethereum founder Vitalik Buterim in 2016 which states that a cryptocurrency can only be two of the following three things: scalable, decentralized, and/or secure [1], [2], [3]. This paper presents research which suggests that the newly emerging science of General Collective Intelligence (GCI) [4] can be leveraged to implement the concept of a "cognitive blockchain" having the capacity to exponentially increase scalablity, decentralization, and security simultaneously. This research suggests that the cognitive blockchain also has the potential to exponentially increase the deployment (market capitalization and use) of both the blockchain and cryptocurrencies.

Background

General Collective Intelligence or GCI, is a hypothetical platform that organizes groups of individuals or intelligent agents working on their behalf into a single collective cognition that might have exponentially greater general problem-solving ability (intelligence) than that of any individual [4]. In order to facilitate this collective reasoning to solve problems that concern understanding the behaviour of any given system, a GCI uses Human-Centric Functional Modeling [5] to define hypothetical “functional state spaces” that provide a common representation of all possible behaviours of that system in terms of paths through that functional state space from one functional state to another. State spaces, which are often used in describing the behaviour of artificial intelligence, differ from functional state spaces in that functional state spaces describe a single domain of behaviour, and in that functional state spaces are hypothesized to be “spanned” by some set of basic operations in that all processes through which the system might transition from one functional state to another can be represented as a composition of those basic operations.

From the perspective of Human-Centric Functional Modelling, as any system executes behaviours, it changes functional state, and therefore moves through its own functional state space. Representing problem-solving in a given domain as “computing” the processes required to navigate a path from one point to another in the functional state space of that domain, and assuming that some minimal set of functions (operations) exists that can be used to compose all processes that solve any problem in a given domain, then having a set of functions that can represent any computational process connecting two functional states potentially creates the capacity for all processes connecting any two functional states to be identified. Being able to uniquely and unambiguously identify processes in functional state space in turn enables the processes to be compared in terms of fitness to achieve their targeted outcome, so that the most fit one can be chosen.

A GCI represents all collective reasoning as some path through a collective conceptual space, and represents all processes of cooperation through which the speed, scale, or any other property of reasoning can be increased, as some path through a "cooperation state space". This includes executing reasoning activities in parallel to increase the speed of collective reasoning, or executing reasoning activities in series to increase the scale of some outcome of reasoning. Through this collective conceptual space, and through this cooperation state space, a GCI has the potential to model any collectively intelligent behaviour through which a group might organize to increase its impact on any collective outcome.

In HCFM every change in functional state is associated with some change in the overall fitness of the system to execute all of its functions. As systems move through their functional state space, they are also represented in HCFM as moving through a "fitness space". In HCFM general problem-solving ability in the cognitive system or in any other system is represented as the system moving through its functional state space in a way that maintains dynamical stability in fitness space [5]. The importance of defining a functional state space as a problem-solving domain is that it has been hypothesized that in every functional state space an exponential increase in general problem-solving ability (ability to solve any problem in general) can be achieved through the same pattern of solution that is predicted to exponentially increase the speed and scale at which this dynamical stability can be maintained [6].

Application of Human-Centric Functional Modeling to the Blockchain

Human-Centric Functional Modeling (HCFM) can be applied to the cognitive system in that every concept (which might consist of a group of concepts) can be considered to be a functional state of cognition, and every reasoning process can be considered to transition the cognitive system from one concept to another. Assuming any functional state in any functional state space can be represented by some concept, then HCFM can be applied to any system that can be conceptualized, with the functional states that are possible for any such system representing some subset of conceptual space (figure 1).

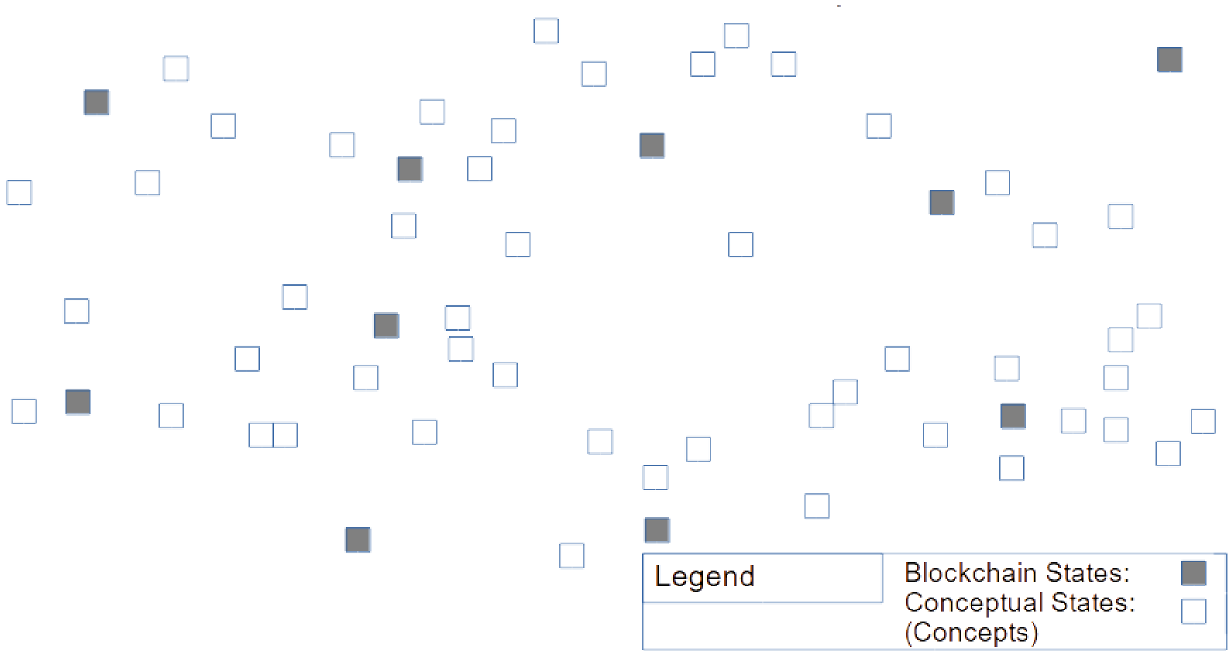

Figure 2. *The functional states of blockchain platforms can be conceptualized and therefore can be represented as concepts. The functional states of blockchain platforms are therefore a subset of conceptual space (the functional state space of the cognitive system).*

The importance of this observation is that if a functional state space can be defined that contains all possible behaviors of a given system in a given domain of behavior, and if general problem-solving ability can be defined as a pattern of dynamical stability in the system's motion through its fitness space as it moves through this functional state space, then GCI, which is predicted to exponentially increase general problem-solving ability, might be applied to the system in order to exponentially increase its ability to solve any problem in that domain.

In discussing functional state spaces it is important to draw a distinction between the functional state space of the cognitive system (the conceptual space) which contains concepts describing some individual's thoughts about the behavior of a system, and the functional state space of the actual system. Humans can develop concepts that are simply wrong in that they don't describe behavior that a given system is capable of. Assume that the cognitive system can reliably "see" any behavior observed in a system in the sense that it can reliably generate concepts describing any observations perceived with any of the five senses, though those concepts might not represent any understanding of the system in that they might not help in solving any problem such as accurately predicting the behavior of the system in any given circumstance. It is then always reliably possible to conceptualize a functional state space describing any given system, but it is uncertain whether it is reliably possible to define a functional state space representing all possible behaviors of the system itself [18].

HCFM might potentially be applied to define functional state spaces for a wide variety of systems, such as the Future Internet [7]. Here it is applied to blockchain technology. While a number of other approaches have been used to model blockchain systems [12], [13], [14], for various applications [15], [16] or for specific purposes like performance [17], the unique benefit of HCFM is introducing the possibility of copying the pattern for exponentially increasing the general problem-solving ability of systems and applying that pattern to blockchain platforms, which suggests the possibility of exponentially increasing outcomes for blockchain platforms.

It is hypothesized that any open (unbounded) functional state space, such as the conceptual space, is spanned by some set of four operations. The conceptual space defined for the cognitive system using HCFM is a graph consisting of a network of nodes representing concepts, in which the connections between those nodes (edges) represent reasoning processes. Hypothesizing that the domain object of the blockchain domain is the blockchain transaction, then just like reasoning processes connect different concepts, different blockchain processes might connect different blockchain transactions, and some four basic blockchain operations might be used to compose all such blockchain processes. In the case of both the cognitive domain [5] and the blockchain domain these four operations have been hypothesized (table 2) but not yet confirmed by implementation. It's important to note that the key claim of this paper is not that the operations in table 1 are the correct set of operations that span the blockchain state space, but that some set of operations spans the blockchain state space.

HCFM hypothesizes that natural systems evolve by adding functionality until that functionality spans a functional state space, at which point the systems can act repeatably and can therefore sustain their activities. But natural systems not only have to accept inputs, they also have to produce outputs in the sense that they need to interact with the external world. That is, in addition to having functionality through which the external world changes the system, systems also need functionality through which they change the external world. In HCFM this is represented as input and output functionality that spans the functional state space describing that particular domain of system behavior.

If what is within boundaries of systems is defined by the ability to change the functional state space of the system, and if what is outside the boundaries of systems is defined by the lack of the ability to change the functional state of the system, then all systems can be represented as interacting with themselves through their functional state spaces. Any entity that can interact with the functional state space of a system is considered to be part of that system. In HCFM externals systems are represented as interacting with the functional state spaces of other systems through representing the functional state spaces of those other systems in terms of signals. For example, a sensation does not have a fixed meaning in the conceptual space, but the cognitive system can reliably locate that sensation among all other sensations through representing it as a "signal" in the sensory field so that signal can then be "conceptualized" and therefore brought into the conceptual space.

Similarly, a blockchain platform modeled in terms of blockchain functional state space might interact with any other system that is also modeled in terms of its own functional state space. These interactions occur through representing points in those functional state spaces as input or output signals. Obtaining the minimal set of blockchain state space spanning operations by directly translating the operations hypothesized to span the conceptual space into operations that act on the subset of concepts that are blockchain transactions does not yield a set of operations that are recognizably useful (table 1), particularly since the operations hypothesized to span the conceptual space have not yet been validated.

Functional Unit	Input Function (to Blockchain Platform)	Output Function (from Blockchain Platform)
F1 to F3 (outside the blockchain platform)	Create Blockchain Transaction from Signals	Create Signals from Blockchain Transaction
F4	STORE (Store Blockchain Transaction)	DECOMPOSE STORAGE (Determine the Blockchain Transaction held in Storage Function)
F5	RECALL (Recall Blockchain Transaction)	DECOMPOSE RECALL (Determine Blockchain Transaction held in Recall Function)
F6	DETECT PATTERN (Detect Pattern in Blockchain Transactions)	DECOMPOSE PATTERN (Detect Blockchain Transaction in Pattern)
F7	DETECT SEQUENCE (Detect Sequence of Patterns in Blockchain Transactions)	DECOMPOSE SEQUENCE (Detect Blockchain Transaction in Sequence of Patterns)

Table 1: *Set of operations proposed as characterizing blockchain platforms.*

Instead of doing so, it's more useful to conduct a functional analysis to determine the common set of functions that all blockchain platforms must perform, as well as an analysis of which of those functions are used to change the platform and are then inputs, and which of those functions are used to change external systems and are then outputs by (table 2).

Functional Unit	Input Function (to Blockchain Platform)	Output Function (from Blockchain Platform)
F4	Collect Transactions to be Stored	Decompose Blockchain Transaction

	in Blockchain Transaction	into Constituent Transactions
F5	Determine Optimal Method of Assigning Right to Add Blockchain Transaction to Blockchain (proof of work, proof of stake or other proof.)	Validate that Blockchain Transaction has been Rightfully Added to Blockchain
F6	Assign Right to Add Blockchain Transaction to Blockchain	Locate Blockchain Transaction in Blockchain
F7	Add Blockchain Transaction to Blockchain	Validate that Blockchain Transaction Belongs to Blockchain

Table 2: *Set of operations proposed as characterizing blockchain platforms.*

The specific operations themselves are not the key claim of Human-Centric Functional Modeling. Instead the key claim is that some set of operations (hypothesized to be four in number) span the conceptual space. The operations hypothesized to span the conceptual space were deduced through the assumption that natural systems (like cognition) evolve by developing one function that results from the interaction of two functional components, then developing a second function that results from the second order interaction between two or more functional components, then developing a third function that results from the third order interaction between two or more second order functional components, and finally developing a fourth function that results from the forth order interaction between two or more third order functional components. When all of these interactions come to span an entire functional state space, it is hypothesized that a system with repeatable behavior is created, where that system can potentially occupy any functional state within that space.

General problem-solving ability in the blockchain domain is then ability to potentially execute a blockchain process through which it might be possible to navigate from any transaction to any other. Since in current blockchain platforms different transactions occur in one platform as compared to the transactions that occur in another, this modeling approach would appear to span multiple or potentially all blockchain platforms.

In the Human-Centric Functional Modeling approach processes in functional state space are represented in terms of the set of functional states they receive as input, the set of functional states they produce as output, and the set of functional states that define the context of execution. As an example, for the function $F = Ax + By$ the values of the variables [x, y] are input, and the values of the constants [A, B] form the context of execution (figure 2).

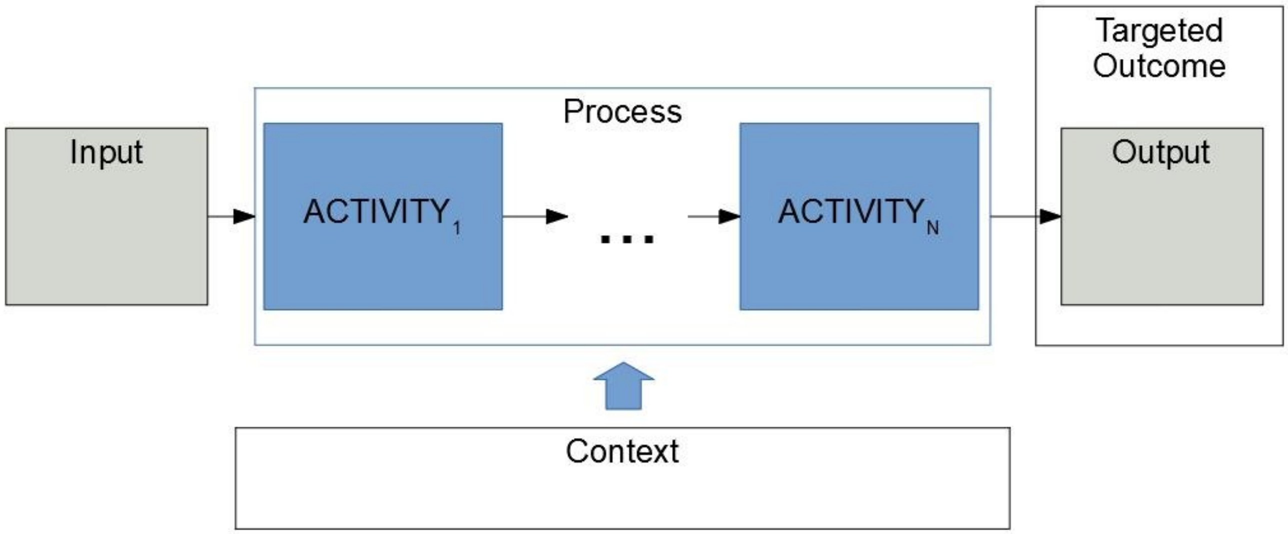

Figure 2. *Functional model of a process in a functional state space such as the blockchain space.*

Each path through this blockchain state space that is taken within each blockchain platform has a different outcome in terms of architecture service level. Some of the elements of architecture service level, and therefore some elements of outcomes in the blockchain state space are security, scalability, decentralization, and reliability. Each function by which a problem might be solved in a given platform has a different fitness in solving that problem in each context.

The Domain of Cooperation

Systems can incorporate multiple adaptive domains in order to increase their problem-solving ability. The cognitive system for example is represented as incorporating the domain of cooperation, which contains the operations required to self-assemble functional components of the cognitive system into massive networks of cooperation that are able to exponentially increase outcomes of problem-solving, and to do so in a self-sustaining way. In addition to the blockchain domain, blockchain platform can similarly incorporate the cooperation domain and can reuse the same set of cooperation functions used in the cognitive system [19]. When used to orchestrate cooperation between the functional components of the blockchain domain such cooperation might exponentially increase ability to solve individual problems in the blockchain state space of the individual user. When used to orchestrate cooperation between nodes in a blockchain network such cooperation might exponentially increase ability to solve collective problems in the collective blockchain state space used by all users. This exponential increase in general problem-solving ability in the blockchain domain implies an exponential increase in ability to solve any blockchain problem in general, which in turn implies an ability to achieve an exponential increase impact on any individual or collective blockchain outcomes in general.

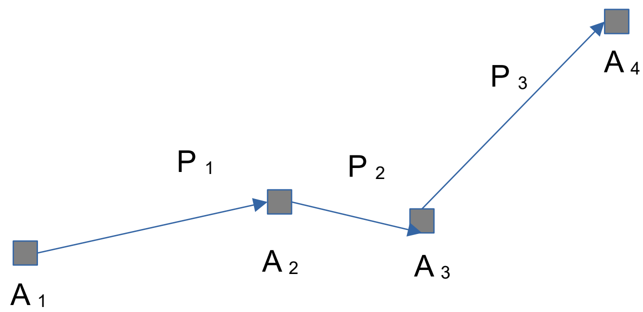

Figure 3. *A cooperation process in cooperation state space. The cooperation process P_1 transitions the system of cooperation from activity A_1 to activity A_2. The cooperation process P_2 then transitions the system of cooperation from activity A_2 to activity A_3, and so on.*

The Cognitive Blockchain

The usefulness of potentially being able to use Human-Centric Functional Modeling to define a single functional model capable of representing any blockchain platform is that while such functional models ignore all details of implementation, such an approach is still potentially invaluable in solving the problem of converging on a single best understanding of which implementation of each function is more fit in a given context. If all blockchain platforms from all vendors can be decoupled into such functional components, where each functional component represents some path segment through the blockchain functional state space, and those functional components added to a library of functional components belonging to single common functional model for all blockchain platforms, then if the fitness of each theory or implementation at achieving that function can be compared, the best component of every model created by any and all researchers can potentially be combined into a single implementation that is most effective. By defining general problem-solving ability as a pattern of dynamical stability in fitness space, a GCI might orchestrate cooperation between all blockchain platform developers to so so far more reliably and far more quickly.

In a cognitive application such as a cognitive blockchain app, intelligent agents working on the sole behalf of some user, where those agents are based on some subset of functionality required for AGI, might be used to find the most fit implementation of each functional operation in each software or hardware domain for that user. If the complexity of processes is defined by the number of steps and the amount of information required to navigate each step, this combination of functional modeling with AGI introduces the potential capacity to manage exponentially greater complexity in order to optimize outcomes for the user. Similarly, in a cognitive platform such as a cognitive blockchain platform, GCI might be used to orchestrate groups to self-assemble into massive networks of self-sustaining and self adapting cooperation that introduces the potential capacity to manage exponentially greater complexity in order to optimize outcomes for all users.

In a hybrid collective intelligence individual humans might interact through a General Collective Intelligence platform that acts as a “global brain” in orchestrating the execution of collective reasoning. That GCI might also enable each individual to interact through any number of intelligent agents working on their sole behalf, so that the scale and rate of collective interaction can be reliably increased exponentially. The incorporation of intelligent agents acting on each individual’s behalf has the potential to exponentially increase the general collective intelligence factor. As an example, a general collective intelligence factor that is 4.21 billion times greater than the average individual intelligence factor of 100 has been suggested to be potentially achievable through implementing the full set of GCI functionality, in a GCI platform in which every human on earth might interact through millions of virtual clones of their personal intelligent agent acting on their behalf, and through incentivizing the participation of those intelligent agents in collective reasoning processes [20]. This implies that although a blockchain platform developed within a GCI would always be expected to drive outcomes that individual humans could detect as improvements in some given area, that platform would likely evolve to accomplish those outcomes through processes that are collectively too complex, and that collectively change at too great a rate and at too large a scale, for any human to understand. In this sense a GCI based blockchain platform is fundamentally different from existing platforms in that the goal is not making better platform design decisions, but instead to transition to a distributed decision-making system that is exponentially more capable of making decisions.

The Cognitive Blockchain as a Virtual Organism

The cognitive blockchain is not just an application or a platform, it is an entire virtual organism that must contain a number of functional components including a hierarchical set of individual and collective patterns of solutions, in order to create the capacity to exponentially increase individual and collective outcomes. As an example, in order to achieve the outcome of vastly increasing the amount of cryptocurrency deployed through the cognitive blockchain, an entire network of collectively intelligent value chains of businesses that use this platform and its cryptocurrency must be defined. Without these value chains, then instead of businesses acting as parts of a virtual organism within which optimizing collective outcomes for all businesses is the stable balance, businesses become an ecosystem of competing entities in which alignment with the interests of some individual decision-maker and potentially undermining collective interests is the stable balance. In other words, although it might seem like a viable option to race to implement the cognitive blockchain functionality described in this paper in order to beat other blockchain platforms to market, any implementation that does not provide a comprehensive roadmap to include all adaptive problem-solving domains defined by Human-Centric Functional Modeling is a platform that is centralized with respect to those missing domains. Any such centralization is a vulnerability that enables some individual to align outcomes with their own interests, and therefore stops the platform from reliably optimizing collective outcomes. Domains that might complement the blockchain domain are identity, data management, security, and a range of others.

The Cognitive Blockchain in Practice

In any current blockchain platform, transactions are performed with security, scalability, and other service level characteristics that are inherent to the platform itself. In a cognitive blockchain application, an intelligent agent might set the security and other properties to optimize outcomes for the individual user according to the needs of the current transaction. Some transactions might be processed and added to the blockchain using proof of work, others with proof of stake. Some transactions might be processes with very little security, others with the highest possible security. In a cognitive blockchain platform, users self-assemble into a potentially massive network of self-sustaining cooperation that optimizes collective capacity to achieve the outcomes targeted by all transactions of all users. Some examples of attributes of blockchain platforms and how they might be scaled are captured in table 3.

Examples of Scaling Blockchain Attributes with Human-Centric Functional Modeling, Intelligent Agents, and General Collective Intelligence
Scale wallet security with N factor authentication
Scale transaction rate with M parallel blockchains
Scale anonymity by distributing transactions over O wallets, over a time T, over a geographic distribution G, over a set of networks S, as well as distributing over other attributes.
Scale privacy by distributing the information of a single transaction over O wallets, over a time T, over a geography G, over a set of networks S, as well as distributing over other attributes.
Scale ability to issue crypto through trusted networks of identified individuals.
Scale ability to issue crypto through untrusted networks of anonymous individuals.
Create ability to perform transactions from a burner phone with only portable software and identity.

Table 3: *Examples of attributes of blockchain platforms and how they might be scaled*

Actually achieving this increase in scale for any targeted outcome requires modeling the logic of process in the appropriate functional state space. Whether represented in some hypothetical security state space, a blockchain state space, or some other state space, any logic is a represented by paths through the collective conceptual space, and therefore by collective reasoning. Any security state space, blockchain space, or other space, as mentioned previously, is then a subset of the collective conceptual space. To scale any outcomes in the collective conceptual space, or in any subset of the collective conceptual space, the cooperation state space is then used.

Example of Exponentially Scaling Transaction Processing Capacity

If each blockchain platform has a given transaction throughput determined by the blockchain length and other factors, then the transaction rate can potentially be scaled by scaling the number of networks that are incorporated into a single platform. This is equivalent to using the cooperation state space to increase the parallelization of processes. For example, if a network Bitcoin B_1 is expected to have a maximum transaction throughput of T_M, then when that maximum is reached a second sibling might be spawned to manage any transaction throughput up to two times T_M. This might continue up to the Nth sibling at which point a new sibling of the parent is spawned (a new “aunt or uncle”) which all subsequent transaction throughput from N times T_M to 2N times T_M might be directed through. Continuing this pattern, once the transaction throughput reaches N^2T_M, then a new sibling of the grandparent might be spawned (a new “great aunt or uncle”) which all subsequent transaction throughput from N^2 times T_M to $2N^2$ times T_M might be directed through (figure 4).

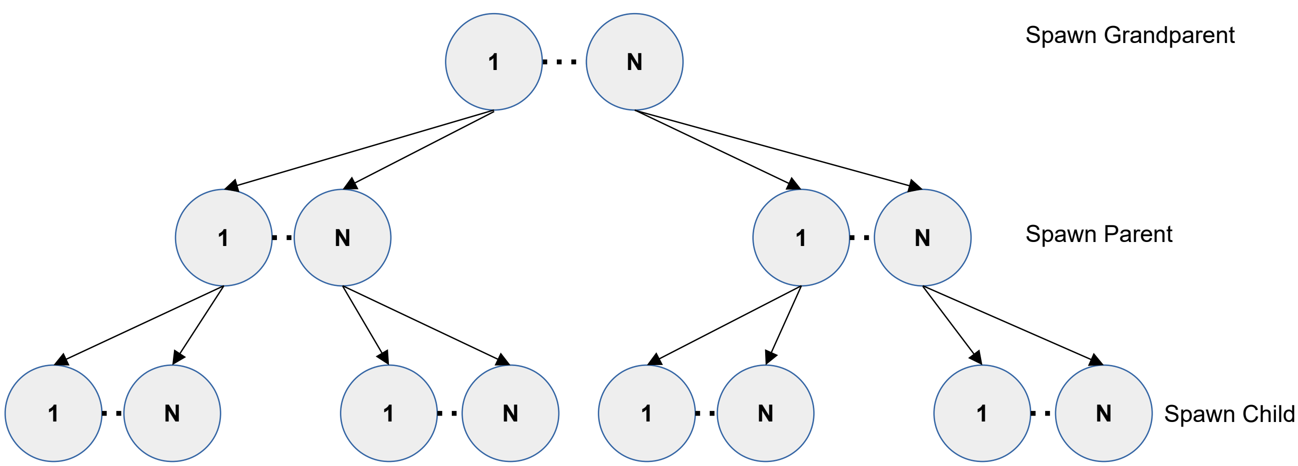

Figure 4. *Scaling blockchain transaction processing.*

If a blockchain functional state space exists such that the logic executed within any blockchain platform can be represented in that blockchain functional state space, then if a cooperation state space exists that cooperation state space can be used to represent any means of distributing that logic to increase the speed and scale of its execution. From this perspective, any blockchain platform such as Solana that takes a particular approach towards achieving scalability is represented as navigating a set of paths through the blockchain functional state space and a set of paths through the cooperation state space. The difference is that a GCI based blockchain platform might decouple Solana and every other blockchain platform into a library of functional components that each represent a set of paths through those functional state spaces. A GCI based blockchain platform might then use any combination of functionality from any platform to exponentially increase the volume of blockchain state space and the volume of cooperation state space that it can navigate, which corresponds to an exponential increase in its capacity to achieve any targeted outcome, and an ability to do so at far greater speed and scale than any team of developers might be capable of without GCI. This means not only replicating and improving upon Solana's ability to scale, but it also means using the functionality of every platform where that functionality is optimal. For example, rather than choosing between proof of work and proof of stake, it means using proof of work in processing transactions for which doing so is optimal (results in the greatest fitness at achieving the targeted outcome), and using proof of stake in processing transactions for which doing so is optimal.

Example of Exponentially Scaling Security

In an environment in which there are N user agents, there are effectively N clones of the user. Where 2 or 3 factor authentication provides a high level of security today, N factor authentication, where N might be in the millions, creates the potential to increase that security to whatever degree required to help ensure that quantum computing or other technologies potentially available in the future will not break security measures. This is equivalent to using the cooperation state space to increase the distribution of security processes. But N factor authentication is only one category of process that a cognitive blockchain might use to increase security. Another might be using millions of agents to break up transactions into many more parts, or sending out random noise to ensure transactions aren't subject to timing analysis. Many other measures remain to be explored. The usefulness of these patterns is that with functional state spaces providing a common functional model they can potentially be applied across all platforms.

Exponentially Scaling Decentralization

It has been said that in many cases cryptocurrency networks are not open for individuals in the general public to participate in either as an actual validator or as a developer and that access can become gated by a clique who determines who can be involved [8]. As mentioned, unlike other crowd computing approaches, a group of people organized by GCI is not merely a crowd, but effectively a single virtual organism. The difference is that a platform like GCI that has general problem-solving ability in the cognitive domain must have the ability to potentially solve the problem of optimizing any collective outcome in general for the group as a single entity. A crowd on the other hand is a collection of entities in which each entity behaves in a way that optimizes their own individual outcomes. Because any crowd computing solution used by such individuals lacks a system for collective optimization, it lacks the ability to reliably achieve collective optimization, which is equivalent to lacking the capacity to solve collective optimization problems. Lacking the capacity to solve collective optimization problems, it does not have the ability to solve any problem in general, and therefore cannot have general problem-solving ability. Problem-solving systems without general problem-solving ability are represented in HCFM as having narrow problem-solving ability. Having narrow problem-solving ability, any crowd computing solution used by such individuals therefore must lack the ability to address all possible collective optimization problems in that domain. In particular, decision-systems with narrow problem-solving ability cannot reliably solve any collective optimization problem that requires changing the parts of itself that the subset of individuals who are decision-makers have aligned with their own individual interests or ideologies and therefore might have ensured cannot be changed. Any blockchain administration or other decision-making process, or any user interface or other tool through which that process is accessed, is a process that can easily become centralized in terms of becoming aligned with some entity's individual interests.

Functional state spaces are hypothesized to be semantic models of systems in that they are capable of providing a complete representation of any system behavior. In order to have the capacity to decentralize any given process, a semantic model of every aspect of that process (and therefore a model of that process in some functional state space), must be defined so that decentralized GCI based processes might enable the group to collaborate in selecting new aspects of that process where they are more fit. As an example, rather than confining a blockchain administration process to a given user interface, a new user interface might be generated from a semantic model of whatever administration process proves more optimal. In order to decentralize all processes in this way a system like GCI must be introduced to enable all those processes to be driven anywhere within the collective conceptual space that optimizes collective outcomes, rather than being confined to the conceptual spaces of some subset of individuals in the group. If the level of blockchain decentralization is the ratio between the number of blockchain related reasoning processes that are paths within some individual's conceptual space and the number of blockchain related reasoning processes that are paths within the collective conceptual space, then the exponentially larger collective conceptual space hypothesized to be achievable through GCI implies an exponentially greater level of decentralization.

Future Work

Deploying a cryptocurrency platform as a single entity makes that entity an administrator [8] which carries certain potential for legal liability. The role of administrator has been defined in the United States, according to guidance published in March, 2013 by FinCEN as follows: "An administrator is a person engaged as a business in issuing (putting into circulation) a virtual currency, and who has the authority to redeem (to withdraw from circulation) such virtual currency" [9].

Any potential liability could be fatal to research efforts directed at implementing the cognitive blockchain [10], [11]. In order to avoid such liability it is intended that any prototype might be released only to a university research network to allow experimental confirmation of the increased scalability, security, and decentralization, until completely decentralized development and administration processes can be implemented to remove liability from any single party. A platform believed to have the potential capacity to support this decentralization (the or Discrete Distributed Work Management Methodology platform or DDWMM platform is currently being designed).

Conclusions

A GCI is a hypothetical blockchain based platform with the capacity to exponentially increase positive social, economic, environmental, or other collective impact where not reliably achievable today by any other known means. GCI can potentially be added to virtually any product or service to gain unbeatable market dominance through exponentially increasing capacity to solve the problem of achieving competitive advantage. Since GCI is blockchain based (the interactions in a GCI are intended to be mediated by micro-contracts stored within a blockchain platform) this has important implications to the future of blockchain technology. The goal of this short paper has been to provide an overview of the concept so that other researchers might independently explore the feasibility of achieving this exponential increase in impact.

References

[1] Conti, M., Gangwal, A., & Todero, M. (2019, August). Blockchain trilemma solver algorand has dilemma over undecidable messages. In Proceedings of the 14th International Conference on Availability, Reliability and Security (pp. 1-8).
[2] Zhou, Q., Huang, H., Zheng, Z., & Bian, J. (2020). Solutions to scalability of blockchain: A survey. IEEE Access, 8, 16440-16455.
[3] Altarawneh, A., Herschberg, T., Medury, S., Kandah, F., & Skjellum, A. (2020, January). Buterin's scalability trilemma viewed through a state-change-based classification for common consensus algorithms. In 2020 10th Annual Computing and Communication Workshop and Conference (CCWC) (pp. 0727-0736). IEEE.

[4] Williams, A. E., Defining a Continuum from Individual, to Swarm, to Collective Intelligence, to General Collective Intelligence, International Journal of Collaborative Intelligence, in press (2021)
[5] Williams A.E. (2020) A Model for Artificial General Intelligence. In: Goertzel B., Panov A., Potapov A., Yampolskiy R. (eds) Artificial General Intelligence. AGI 2020. Lecture Notes in Computer Science, vol 12177. Springer, Cham. https://doi.org/10.1007/978-3-030-52152-3_38
[6] Williams, A. E. (2022, March 12). Automating the Process of Generalization. https://doi.org/10.31730/osf.io/fb4us
[7] Williams, A. E., & Petrovic, N. (2021, January 12). The Role of Cognitive Computing and Collective Cognitive Computing in the Future Internet. https://doi.org/10.31730/osf.io/qb7sm
[8] Tim Swanson, Who are the administrators of blockchains?, Published Aug 19, 2017, retrieved on Aug 12, 2021 from https://www.ofnumbers.com/2017/10/19/who-are-the-administrators-of-blockchains/
[9] Application of FinCEN's Regulations to Persons Administering, Exchanging, or Using Virtual Currencies, Issued Date March 18, 2013, retrieved on Aug 12, 2021 from https://www.fincen.gov/resources/statutes-regulations/guidance/application-fincens-regulations-persons-administering
[10] Walch, Angela, Open-Source Operational Risk: Should Public Blockchains Serve as Financial Market Infrastructures? (December 2, 2016). Chapter in Handbook of Blockchain, Digital Finance, and Inclusion, Vol. 2, Eds. David Lee Kuo Chuen and Robert Deng, Elsevier (2017), Available at SSRN: https://ssrn.com/abstract=2879239
[11] Walch, Angela, BankThink Call Blockchain Developers What They Are: Fiduciaries, published August 09, 2016, 12:00 p.m. Retrieved on Aug 12, 2021 from https://www.americanbanker.com/opinion/call-blockchain-developers-what-they-are-fiduciaries
[12] A. V. Spirkina, E. A. Aptrieva, V. S. Elagin, A. A. Shvidkiy and A. A. Savelieva, "Approaches to Modeling Blockchain Systems," 2020 12th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2020, pp. 242-247, doi: 10.1109/ICUMT51630.2020.9222437.
[13] H. Rocha and S. Ducasse, "Preliminary Steps Towards Modeling Blockchain Oriented Software," 2018 IEEE/ACM 1st International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB), 2018, pp. 52-57.
[14] C. Kaligotla and C. M. Macal, "A GENERALIZED AGENT BASED FRAMEWORK FOR MODELING A BLOCKCHAIN SYSTEM," 2018 Winter Simulation Conference (WSC), 2018, pp. 1001-1012, doi: 10.1109/WSC.2018.8632374.
[15] Vladyko A, Spirkina A, Elagin V. Towards Practical Applications in Modeling Blockchain System. Future Internet. 2021; 13(5):125. https://doi.org/10.3390/fi13050125
[16] Y. Yuan and F. Wang, "Blockchain and Cryptocurrencies: Model, Techniques, and Applications," in IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 48, no. 9, pp. 1421-1428, Sept. 2018, doi: 10.1109/TSMC.2018.2854904.
[17] H. Sukhwani, N. Wang, K. S. Trivedi and A. Rindos, "Performance Modeling of Hyperledger Fabric (Permissioned Blockchain Network)," 2018 IEEE 17th International Symposium on Network Computing and Applications (NCA), 2018, pp. 1-8, doi: 10.1109/NCA.2018.8548070.
[18] Williams, A. E. (2022, March 12). Selecting Between Semantic Modeling of Intelligence and Semantic Modeling of Systems. https://doi.org/10.31730/osf.io/gdn5y
[19] Williams, A. E. (2022, March 2). General Collective Intelligence as a System for Facilitating Parallel and Distributed Computing. https://doi.org/10.31730/osf.io/m7rfh
[20] Williams, A. E. (2022, February 22). Defining and Quantifying an Exponential Increase in General Problem-Solving Ability Within Groups. https://doi.org/10.31730/osf.io/98pe7