Defining the Genome and Gametes of a General Collective Intelligence Based Smart City

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Abstract

Applying General Collective Intelligence or GCI creates the potential to greatly increase the complexity of problems that might be navigated through collective reasoning processes, and to greatly increase capacity for cooperation in so that collective reasoning might be executed at much greater speed and scale. GCI also aligns cooperation so those outcomes can be sustained. Applying GCI to design processes creates the potential for designs for products and services, as well as manufacturing methods for products and delivery methods for services, that are coherent on a scale that might not have been considered before. Where smart city initiatives look to introduce sustainability into housing and city design, GCI based design aims to gain the capacity to self-assemble projects in a way that optimizes sustainability across all initiatives. This paper explores how the full implementation of GCI in design defines a genome with the capacity to store collectively optimized processes, and how the full implementation of GCI in manufacturing and construction defines gametes with the capacity to be collectively optimized in this way.

Keywords: General Collective Intelligence, Human-Centric Functional Modelling, smart city, smart housing

1. Background

General Collective Intelligence or GCI has been defined as a platform that combines individuals into a single intelligence with the potential for exponentially greater general problem-solving ability (intelligence) than any individual [1], [2]. GCI requires decomposing problems into a common functional model so they can be solved by a common set of cognitive computing operations that can be distributed over the whole group. This entails a single functional model with the capacity to represent all designs, and a single functional model with the capacity to represent all manufacturing operations and equipment. The approach of Human-Centric Functional Modelling (HCFM) [3] is proposed to provide a solution to achieving this comprehensive functional model. A genome is the complete set of genetic information in an organism. And gametes are an organism's reproductive cells. Here the concept of a genome of an entity is generalized to represent the minimal information store that can be used to reproduce the entity. And here the concept of gametes are generalized to represent the minimal set of self-replicating structures that can be used to replicate an entity from its genome. The collective genome is represented as the minimal set of designs that can be used to derive all existing designs in smart cities within a smart civilization. And the collective gametes are defined here as the minimal set of manufacturing processes and equipment that can reproduce all products and services, and therefore can reproduce all manufacturing processes or services.

2. Introduction

Currently, design and manufacturing processes compete to create competitive advantage for their owners. This competitive advantage enables companies to acquire more resources to support the design and manufacturing of additional products and services in order to gain more resources to create more competitive advantage.

In order to support this cycle, consumption on the part of the consumer must be maximized. However, General Collective Intelligence or GCI creates the potential to exponentially increase the general problem-solving ability of the group, as well as creating the potential to exponentially increase the group's ability to increase the scale and speed of cooperation, so that competitive advantage through cooperation is reliably achievable. This collectively intelligent cooperation has the potential capacity to increase any common element of collective well-being, potentially even reducing consumption while at the same time creating competitive advantage for the cooperating group, rather than being constrained to individual competition and the ensuing race towards increased consumption that might actually do collective harm.

3. Related Work

Though others have described the concept of a general collective intelligence factor (c factor) [4], though at least one other has defined a model for a general collective intelligence factor [5], and though others have described the concept of a collective super intelligence [6], to the author's knowledge the author's own work is the only model that defines the specific mechanisms required for a General Collective Intelligence or GCI with the potential for exponentially greater general problem-solving ability (intelligence) than any individual [1]. Because of this, and because this model is so new, all of the existing literature surrounding GCI refers to the author's own published work, or pre-prints of the author's unpublished work that is still under review.

4. Purpose, Research Questions, and Approach

The purpose of this paper was to demonstrate that using functional modelling and General Collective Intelligence to define the collective genome and the collective gametes of a smart city is required to create the capacity to continuously maximize sustainability or any other outcome achieved through any housing, utilities, or any other product or service deployed in that smart city.

The research questions addressed in this paper and the method with which they were approached are described below:

Section 4: Research Question Addressed

4.1. Can GCI be used to define processes that act as a genome for smart cities, creating the capacity to store collectively optimized designs?

4.2. Can GCI be used to define manufacturing, construction, and other implementations processes of those designs, where the implementations act as gametes with the capacity to be collectively optimized in this way?

Section 5: Model

5.1. Key functionality of General Collective Intelligence.

5.2. Enabling smart city processes to leverage General Collective Intelligence.

Section 6. Method

6.1. The concept of a collective "genome" was generalized using a functional approach.

6.2. The process of General Collective Intelligence based design was generalized and an assessment was made to determine whether it might form a collective genome.

6.3. The concept of collective "gametes" was generalized using a functional approach.

6.4. The process of General Collective Intelligence based manufacturing was generalized and an assessment was made to determine whether it might form collective gametes.

Section 7. Findings

Section 8. Research Limitations

Section 9. Practical Implications

Section 10. Conclusions

5. Model

Aspects of the model of collective cognition that are relevant to the research questions are described below.

5.1. Key Functionality of General Collective Intelligence

The key functionality of GCI with regards to outcomes targeted by smart city initiatives are using adaptive problem-solving to optimize outcomes, and using collectively intelligent cooperation to increase those outcomes.

Collectively Intelligent Adaptive Problem Solving

In a GCI a problem is a gap between one point in the collective conceptual space that represents one concept, and another point in the collective conceptual space that represents a second concept. A solution is a set of reasoning processes that form a path between those two points. General problem-solving ability (intelligence) is represented by the volume of conceptual space that can be navigated per unit time. GCI increases the intelligence of the group through a set of functionality [7] that combines the reasoning processes of each individual in the group into a collective reasoning process. This collective reasoning is an adaptive problem-solving system that creates the capacity to potentially incorporate all the information and reasoning processes possessed by every individual in the group. In conceptual space the depth of complexity of problems is represented by the length of the sequence of reasoning processes involved, and the resolution in conceptual space that each point (concept) in the reasoning is defined at. The breadth of complexity of problems is represented by the volume of conceptual space the reasoning involves. GCI has the potential of exponentially increase the overall complexity of problems that can be defined and solved [8].

Collectively Intelligent Cooperation

Assume that simple cooperation between two parties can be represented by a first order barter transaction in which one entity exchanges some value in return for the other party exchanging an approximately equal value. And assume that complex cooperation can be represented by Nth order barter transactions in which the first party gives something to the second party, who gives something to the third party, and so on until the N-1 th party gives something to the Nth party. Nth order barter transactions can enable a GCI to optimize collective outcomes over an unlimited number of possible chains of cooperation, to the capacity of the cooperating entities to engage in that cooperation. In an open Nth order barter transaction, value is provided to the first party from outside the chain of cooperation. This cooperation can potentially be applied to the execution of any process, including manufacturing or design. In the case that the open Nth order barter transaction is a design process, this value might be the improved outcomes that are achievable through the design of a specific product or service, this value might create demand for goods at one end that supports the entire chain of cooperation. Because each product or service in the chain of cooperation is guaranteed demand by the product or service before it, chains of cooperation can then be scaled up to the total available demand. At the same time, chains must be restricted by the limits imposed by any design or manufacturing processes within any product or service within the chain of cooperation.

Since outcomes can be scaled by collectively intelligent cooperation, since the value of outcomes can be directed towards providing competitive advantage for the group, and since collectively intelligent cooperation can be scaled in this way, then wherever a given level of outcome achieved by a product or service in the chain of cooperation provides competitive advantage, that competitive advantage can always be increased to any arbitrary level, within these limits, that is, within the capacity of the system of cooperating entities to engage in cooperation. Since the products and services that can potentially be involved in this cooperation are any product or service of any entity in the collective, as opposed to being limited to the products or services that might possibly align with the narrow interests of a single company, this competitive advantage for the collective then can reliably be increased to the point at which it is unbeatable.

5.2. Enabling Smart City Processes to Leverage General Collective Intelligence

The key requirements that processes must adhere to in order to facilitate the application of GCI is that they must be designed so they can operate in a peer-to-peer, user-centric, decentralized, and massively collaborative way so that outcomes might be scaled through cooperation. This means designing processes with virtual properties (owner, physical context execution, etc.) so that execution of processes can be transferred and so others with access to additional resources can be engaged. Software designed this way might be used to orchestrate massive collaboration. Execution of software designed this way might be facilitated by a platform designed to manage such decoupled processes [9].

Collective Intelligence Based Design

In collective intelligence based design, a human-centric functional modelling approach is applied to develop functional models of systems being researched, designed, or developed, so that the GCI can use its adaptability functions to orchestrate cooperation among individuals to adapt the model of that design process to improve its fitness at achieving its targeted outcomes, and so that the GCI can decouple components of the design through applying the principles required for intelligent cooperation. In doing so, GCI creates the potential to maximize collective outcomes that can be achieve with that design.

Where conventional design processes might look to gain competitive advantage for a single company, GCI based design process might look to gain competitive advantage for a group of several million companies that are cooperating together. By algorithmically mining all possible chains of cooperation, this cooperation might reliably create enough value that companies can gain unbeatable competitive advantage by actually cooperating to create better, cleaner, and longer-lived products that reduce consumption and waste. Where even the best intentioned programs to address environmental degradation related to climate change and other issues must drive increased consumption in order to achieve economic growth, GCI based design might create the potential to grow while reducing consumption. That is, it might create the potential to achieve “green growth”.

Another key way that GCI aims to optimize collective outcomes is by defining a stable dynamical path in the “fitness space” of the GCI, so that the GCI can constantly re-evaluate whether it is solving the right problem according to whether it is becoming more stable or less stable. That is, so the GCI might choose which problem it focuses on according to which problem has the greatest projected impact on the stability of fitness, taking into account factors such as whether the projected impact is achievable within currently available resources, and whether projections match with actually observed results, in order to remove any constraints that might force groups to solve the wrong problem. In the current model of GCI, the dynamics between projected, targeted, and actual impact form a stable convection to help ensure maximization of collective outcomes can be sustained [7].

Collective Intelligence Based Manufacturing

In collective intelligence based manufacturing a human-centric functional modelling approach is applied to develop functional models of systems and tools used for product production, or for services delivery. Again, these models enable a GCI to use its adaptability functions to orchestrate cooperation among individuals to adapt that model to improve fitness at achieving targeted outcomes, and enable the GCI to decouple components of that manufacturing or delivery through applying the principles required for intelligent cooperation. In doing so, GCI creates the potential to sustainable maximize collective outcomes that can be achieve with that manufacturing or delivery process.

6. Method

The research questions were addressed using the methods summarized in table 2.

Table 2. Components of cognitive process execution.

Research Question	Method
1. Can GCI be used to define processes	1. The concept of a collective “genome”

that act as a genome for smart cities, creating the capacity to store collectively optimized designs?	was generalized using a functional approach. 2. The process of General Collective Intelligence based design was generalized and an assessment was made to determine whether it might form a collective genome.
2. Can GCI be used to define manufacturing, construction, and other implementations processes of those designs, where the implementations act as gametes with the capacity to be collectively optimized in this way?	1. The concept of collective "gametes" was generalized using a functional approach. 2. The process of General Collective Intelligence based manufacturing was generalized and an assessment was made to determine whether it might form collective gametes.

5.1. Generalizing Collective Intelligence Based Design into a Collective Genome

Applying the concept of a genome to entire smart cities begins with generalizing the concept of a genome.

Generalizing the Concept of a Genome
A gene is the basic physical and functional unit of heredity. A genome is an organism's complete set of genetic information, containing all of the information needed to self-assemble the physical structure of that organism through growth, development, and other processes. In addition to being a store of growth and development processes, the genome must also store processes that enable optimization and adaptation of other processes. In order for optimization to be possible across any organism that might arise from a genome, that optimization must act on some universal functional models that apply to all such implementations of the genome. The process of optimization itself must also be optimizable. Therefore all processes in a collective genome must be stored in some functional model.

Representing a smart city within a smart civilization as a collective organism, any self-assembling functional model of that civilization that contains all of the information needed to build and optimize the physical structure of that civilization, might be represented as the collective genome.

Using GCI to Optimize Across all Design Problems
After functional models of all products and services created by the group have been defined, these functional models might eventually be aligned by GCI into a developmental hierarchy. If products P_{1i1} to P_{1iN} or services S_{1i1} to S_{1iN} are required as inputs to the manufacturing process for component P_{1i} of product P_1, and products P_{j1} to P_{jM} are required as equipment, or services S_{j1} to SjM being required as activities in the manufacturing process for component P1i of product P_1, then by defining Nth order chains of cooperation between this matrix of products and services it might be possible to design all products and services such that they can be constructed from a basic set of self-contained set of functionality. Or in other words, the most basic products and services might be constructed from a basic set of building blocks. And such building blocks might be used to construct other building blocks (or if their functionality included replication, might construct those other building blocks themselves), that might construct other building blocks, that might eventually construct all existing products and services. Once all designs have been aligned into a single hierarchy that can be constructed from a minimal set of functional components, then the set of all functional models of all designs for all products and services effectively forms a "collective genome".

Where the ability of any current smart city initiative to achieve sustainability or to achieve impact on goals such as carbon emission might be limited to what can be achieved through the design of individual products or services, design based on collectively intelligent cooperation can potentially provide unbeatable competitive advantage for those who cooperate to maximize any collective outcome. If each participant in the collectively intelligent design cooperation increases outcomes by some marginal amount, and if GCI can scale this participation exponentially, then the collective genome formed by aligning functional models of designs can enable this smart city to be collectively optimized to increase outcomes by potentially orders of magnitude.

General Collective Intelligence is an example of biomimicry. From a functional modelling perspective, life can potentially be represented as a hierarchy of adaptive processes including homeostatis, reproduction, evolution, and others that each provide the capacity to adapt in different functional domains [10], [11]. Part of using collective intelligence in design is defining design processes that can be adapted by a GCI across these various domains.

Nature sometimes chooses the evolutionary strategy of differentiating organisms into many different species capable of occupying different niches. And, in the form of human beings, it has at least once chosen the evolutionary strategy of differentiating life into one organism capable of intelligently adapting to potentially all different niches.

One of the principles that govern the way organism as a collection of cells are designed, is that the functional components of an organism might change. A group of cells might differentiate into multiple functional components, or they might combine into a single one. Organisms might differentiate into different species that fill different niches. Or a single one might assume multiple niches.

All processes have targeted outcomes. Design processes with the capacity to be adapted by a GCI must be defined in terms of functional models so that GCI can operate, and must be able to potentially navigate to any unexplored area of the “design configuration space” (space of all possible designs). To do so GCI must be able to adapt these processes to increase their fitness in achieving their targeted outcomes. This includes dividing into multiple different components when the targeted outcomes are too divergent, or combining into a single component when the targeted outcomes are too similar.

The importance of a collective genome able to store interactions between design processes is that such interactions might be stored at a far higher order of complexity than currently possible, and therefore optimized across a far higher order of interactions that currently possible. Examples of higher order interactions that might be stored in such a collective genome include interactions between designs, interactions between interactions between designs, interactions between those interactions, and so on.

Our System of Organization is our DNA

One might construct an argument that any collective system of organization acts as the "DNA" of the collective. And just like the DNA of any animal governs how, as it evolves, its cells differentiate into different body parts and organs comprised of neurons and other cells, one might intuit that a system of organization as the DNA of the collective might by analogy determine, at least in part, how its individual components evolve. Another part of how organisms evolve is how their DNA is expressed. GCI can potentially create the capacity to individually customize all products or services in order to optimize outcomes such as sustainability [15]. If a GCI and a hierarchy of functional models of designs are the system of organization of a smart city and therefore it’s DNA, the process of individually customizing products or services using AGI [12] or GCI in order to optimize outcomes is the expression of that DNA.

In the natural world, each creature has an intrinsic set of adaptive strategies, that is, each design encoded in a particular species through its DNA has an intrinsic set of strategies by which it's built to achieve its survival at this point in time. And it has an intrinsic set of strategies in each adaptive domain which it can respond to environmental pressures by changing to better achieve its survival in the future. The rate these strategies can change in each adaptive domain has limitations.

In the Functional Modeling Framework (FMF) [13] used to define this model of GCI, one of these adaptive domains is reproduction, assuming sexual reproduction, each creature must retain genetic compatibility with others in their species in order to pass on their genes. For a GCI based smart city in which each design might be required to be compatible with a network of millions or billions of components, a "reproductive algorithm" might similarly be needed to reproduce designs for new purposes, while also modifying them in a way that maintains compatibility.

Another adaptive domain in the FMF is evolution. Evolution can't change an organism so much in one generation that it breaks this compatibility. For this reason, the evolutionary strategies of living things likely must evolve in a continuous way, without great jumps. For a GCI based smart city, an "evolutionary algorithm" might similarly be needed to coherently modify designs over multiple reproductive cycles.

If a civilizational DNA is analogous, then any adaptation, such as gaining the capacity to exponentially increase collective outcomes and the sustainability of those outcomes, might likely require DNA be expressed through adaptive domains in some similar way that enable it to adapt incrementally in a way that maximizes some dynamical stability. Having gained that dynamical stability, a civilizational DNA may not be capable of discontinuous jumps, even if envisioned by some single wildly imaginative person. But at the same time, the ability to radically increase capacity to evolve might also be created.

5.2. Generalizing Collective Intelligence Based Manufacturing into the Collective Gametes

Applying the concept of gametes to entire smart cities begins with generalizing the concept of gametes as well.

Generalizing the Concept of Gametes

Gametes are an organism's reproductive cells. There are two types of gametes. Each carries only part of the genome in order to introduce the possibility of differentiation. One gamete contains the resources required to initiate construction. The other contains some key information determining the properties of what will be constructed. Behavioural processes are one adaptive problem-solving domain. As with all adaptive problem-solving domains, behaviour might be determined at least in part by the genome, and in part by environmental factors such as the way the genome is expressed. The combination of assigning specific adaptive behaviours to organisms that produce two type of gametes, and assigning responsibility for certain offspring traits to each of those gametes, together ensures that reproduction will ensure the entities with the most fit implementations of those behaviours will determine those characteristics. In other words, if characteristic "A" is in the part of the genome carried by the "male" gamete, and the fitness of certain behaviours in that male determine whether that male is selected for reproduction, then the fitness of those behaviours in the parent male determines characteristic "A" in their offspring.

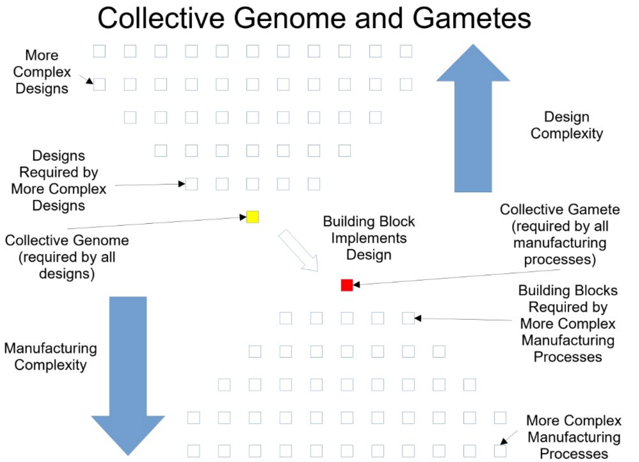
This correlation of fitness of processes in one adaptive domain with selection of processes in another adaptive domain might enable adaptation to span potentially all domains. For example, if the genome of a smart city consists of a hierarchy of designs, then two smart cities might have different genomes. Any process of reproducing those designs to a third smart city would benefit from taking the best designs from both. But determining which designs are best requires that reproduction is based on some behaviour determining which city is most fit, perhaps the amount of green space with which city is constructed so that the city encourages citizens to live more healthy lifestyles. That behaviour then determines the attribute of “green space”.

Using GCI to Optimize Across all Manufacturing Problems

Having defined a hierarchy of designs for all components that maximizes impact on all outcomes, the most basic building blocks that can come together to execute that collective design to manufacture the entire hierarchy of products and services might be defined in a way so that they form "collective gametes".

In order to do so, the building blocks must be defined to have the basic set of resources required to initiate manufacturing processes that self-assemble in ways that create additional manufacturing capacity. And those building blocks must contain processes by which different collective genomes (collections of designs) can be selected and expressed. This self-assembly can involve manual human processes, or it might be fully automated.

For example, two collective gametes might each be represented by a bot with basic manufacturing capabilities. At least one of those bots will require the physical resources and energy to begin manufacturing. And each gamete might specify different manufacturing processes for the same component. In the case of certain processes there might be selection processes that determine the relative fitness of one those two types of bots in implementing those manufacturing processes. That one of the two types of bots might then effectively select which of those manufacturing processes is implemented. However, as mentioned, the processes of assembly might be manual. Such bots are not needed for the concept of a genome to be useful.



If there are selection processes within the manufacturing process that determine the relative fitness of any functional component of design, the manufacturing process itself might select which designs are implemented.

Figure 1. A hierarchy of designs is contained in the collective genome. A hierarchy of building blocks for manufacturing (products) or implementation (services) is contained in the gametes.

As in the case of the collective genome, the importance of collective gametes able to store interactions between manufacturing processes is that such interactions might be stored at a far higher order than currently possible, and therefore optimized across a far higher order of interactions that currently possible. For example, this creates the potential to store interactions between manufacturing processes, interactions between interactions between manufacturing processes, interactions between those interactions, and so on.

6. Findings

As detailed in table 3, the answer as to whether GCI and functional modeling can be used to define a collective genome and collective gametes in order to optimize collective outcomes such as sustainability appears to be yes.

Table 3. Research Findings.

Research Question	Findings
1. Can GCI be used to define processes that act as a genome for smart cities, creating the capacity to store collectively optimized designs?	1. The answer appears to be yes. But much more work is required to define an implementation for the concept of a collective genome so that implementation has the capacity to be used for adapting

	design and other processes.
2. Can GCI be used to define manufacturing, construction, and other implementations processes of those designs, where the implementations act as gametes with the capacity to be collectively optimized in this way?	2. Similarly, the answer appears to be yes but much more work is required to define an implementation for the concept of a collective gamete so that it might not only self-assemble but also select which designs to express.

7. Research Limitations

Though models of a number of proposed GCI solutions have been defined in agriculture, health care, and other fields, and though conceptual case studies of these solutions have demonstrated the potential for the exponential increase in impact on outcomes as suggested might be achievable in this paper, GCI has not yet been implemented. As a consequence, many details inevitably remain to be clarified.

Furthermore, as described elsewhere [8] GCI is a complex system that must likely in effect be grown through initiating a self-assembling process that adapts in any way required to maximize collective outcomes rather than being developed in a top-down way that can become tightly coupled with centralized interests. Defining a simple functional model of GCI alone is not sufficient to implement GCI. An understanding of the self-reinforcing networks of cooperation and hierarchy of their deployment that is required [14], an understanding of the application of GCI to the customization of products and services deployed in those networks [15], an understanding of the platform required to execute processes with a GCI [9], as well as an understanding of the application of GCI to research, design and all the other processes in the business life-cycle might be required [16]. In the same way that defining a simple functional model of the human system as containing a heart to pump blood, lungs to oxygenate blood and remove carbon dioxide, as well as containing other functional components is not sufficient to clone a human being. However, the process of understanding how to implement a GCI must begin with an understanding of the functional components required.

8. Practical Implications

Ongoing work continues to explore how General Collective Intelligence might be used to orchestrate massive collaboration in design [17], as well as in manufacturing [18], [19], and how that GCI based manufacturing and design might reliably achieve collective sustainable outcomes that might not be reliably achievable otherwise [20], [21]

With a collective genome capable of storing processes of higher order complexity (involving interactions between processes where those interactions require the ability to navigate higher levels of complexity than currently possible), and with collective gametes capable of expressing those interactions from this stored information, then design and manufacturing processes might include interactions that are far higher order, and therefore far more complex than currently possible.

The categories of products too complex to manufacture currently include much biological machinery. For example, rather than manufacturing a calculator, perhaps through such a GCI based manufacturing process one might simply grow one. The difference between growing and manufacturing a calculator is that in growing the manufacturing processes must be contained within the interactions possible for the device. And the design for those manufacturing processes must be stored within the device itself.

Functional models of designs and manufacturing processes stored in a conceptual space defined within an HCFM approach might be independent of language and so might be understood by any civilization to come, without any mapping to that language (i.e. without a "rosetta stone") being required. Such functional models would have the effect of providing human civilization with far greater resilience to any catastropic event, because society might be reconstructed even if computer systems or operating systems capable of reading whatever media format that knowledge has been stored in are no longer in existence and can't be recreated before that knowledge is lost.

Whether or not they have the capacity for general collective intelligence, the products and services designed by a civilization, and the manufacturing tools and processes required to create them are the physical manifestation, or in a sense the physical "body", of its collective intelligence. Therefore these design of these products and services are also as a manifestation of its "civilizational DNA". The intrinsic evolutionary strategy of this civilizational DNA might ostensibly cause differentiation of physical and virtual products and services into a vast number of competing designs, by analogy with the process of evolving into different species. Or, in analogy with evolving into a single multi-celled intelligent creature, it might cause those products and services to become better integrated into a single General Collective Intelligence by maximizing their capacity to perform some function that is aligned with the function of all other products and services in a way that best serves the collective well-being.

What causes one DNA to evolve as a single creature, while another evolves into a vast number of competing creatures? And by analogy what causes one product or service to evolve as a single product or service, while another evolves into a vast number of competing products and services? As an example of a single coherent design plan given by the design of the human body, human beings have one heart, not two hearts, perhaps because they might compete. But humans have two lungs, perhaps to provide greater resilience to the respiratory system. However, humans don't a second set to compete with the first two. This contrasts with, for example, the design of the typical city’s rush hour gridlocked transport systems. Lacking collective intelligence, they are designed so that parts are either not integrated or are incompatible, leading to much more inefficiency.

9. Conclusions

All of this leads to some powerful conclusions. One is that design for general collective intelligence is one way that any system in a smart city, whether healthcare, education, renewable energy, or other systems, can be independently designed in a way that self-assembles to converge on a single set of principles that maximizes collective outcomes, with that design being driven by the entire collective rather than a single actor. And another is that being driven by the entire collective, design and manufacturing can't escape incorporating the needs of the entire collective. Designing for general collective intelligence then has the ambitious scope of serving the needs of everyone.

The design and manufacturing or delivery of physical and virtual products and services using General Collective Intelligence creates the opportunity to maximize collective outcomes. And the principles of that GCI based design and of that GCI based manufacturing are beginning to be laid out. This is an example of biomimicry, since human bodies as an intelligent collection of cells reflect these design and manufacturing principles. Nature has solved all the problems in optimizing outcomes for collections of entities in the way that it encodes the information of living things into stable genetic level, behavioural level, as well cognitive level, and other processes. GCI addresses the challenge of storing the "DNA" of civilization and of creating “gametes” with the potential to reliably express that DNA to reproduce all existing products or services.

Acknowledgements.

Thanks to Julian Talev for countless discussions on the topic.

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