A design of a cyclic universe (I).

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Abstract

The model of the universe is defined as an isolated system. It is represented by a coherent, directed, random network. The network consists of nodes, connections and a demiurge who randomly modifies these connections according to the urns model. We show that is possible to manipulate the entropy in this isolated system by changing the protocol by which the demiurge modifies connections. Two protocols result in expansion with increasing entropy. Four protocols result in contraction with decreasing entropy. A combination of these protocols results in a cyclic universe.

What is further demonstrated is that - in spite of the random behavior of the demiurge - there is a form of self-organization in the network. The structure of the expansion protocols triggers the so called Matthew Effect. Even at a level of maximum entropy the network is relatively more populated by complex structures (measured by the number of connections) than by simple ones.

Finally, it is shown that a state of "omniscience" is impossible. The information content of the model universe is much lower than the information that is needed to describe its state. Within this universe an entity that is omniscient cannot occur.

1) Background

The design of a universe that we present in this article is one in a long series. It will not be the final design and it is certainly not the first. Most of the known designs are of religious nature. One assumes an omnipotent God who creates the universe. One of the first non-religious designs stems from Greek antiquity. In the dialogue *Timaeus*, Plato describes how the world came into being. According to Plato, the world comes forth from chaos, a chaotic arrangement of **elementary stuff**. This basic stuff cannot be reduced to something simpler. The stuff is not created, but it's just there. He then introduces a craftsman: the demiurge. All the demiurge does is organizing the stuff according to eternal forms. In this way he gets **order** out of chaos. You can think of it as the way a potter makes an image. Chaos is the condition where clots of clay lay scattered around. The molder tames the chaos by arranging the clots of clay into a coherent image.

The progress of natural sciences

Meanwhile, it is nearly 2,500 years later. Natural sciences have made great progress. We will focus on four key areas.

Elementary stuff. Theories about the fundamental building blocks of nature and their organization have resulted in the Standard Model of elementary particles. Our material world is ultimately constructed from exotic particles like quarks and leptons. Enormous particle accelerators have been able to verify that model. Because of this success, the model is considered as a "theory of almost everything".

Probabilistic laws of nature. An equally big success story is quantum mechanics. It turns out that the universe exhibits, at the deepest level, random behavior. One cannot determine with certainty the behavior of subatomic particles. Nevertheless, laws of nature have been discovered that predict with incredible accuracy this random behavior, not as a certainty but as a probability.

Cosmogony. A third milestone relates to cosmogony: how did the universe came into being? The current cosmological insights that are based on many very accurate astronomical observations show that the universe originated 13.7 billion years ago. This genesis moment is called the Big Bang. The occurrence of the Big Bang is not only supported by observations but can be derived directly - under the assumption that matter is evenly distributed in the universe - from the general theory of relativity.

Entropy. The development of the universe from the Big Bang to the present day can be summarized by the concept of entropy. Entropy can be defined as the amount of information needed to describe a certain state. How orderly the state, the less information one needs and the lower the entropy. And vice-versa. In the course of time an important observation was made: entropy always seems to be increasing. This observation resulted in the Second Law of Thermodynamics which can be formulated as follows: the entropy of an isolated system that is not in equilibrium increases with time until the maximum for that system is reached. The state with the maximum entropy is the equilibrium state. When one substitutes the term "isolated system" by the word 'universe', one gets the famous statement of Clausius from 1865: the entropy of the universe tends to a maximum. And that means that the universe that orderly took off with the Big Bang will end in a desolate, chaotic state.

One could say that a lot has been achieved. We know the fundamental building blocks of nature and their organization. We know the most important fundamental laws of nature and know how they work. We almost certainly know how the universe was formed. And we know with great probability how the universe will come to an end. But do we?

Although our knowledge of nature has exponentially grown in the last hundred years, there are still big gaps in our understanding. Can we bridge these gaps in the next years by applying our highly successful scientific method in the usual way? Or do we bump against the limits of this method and have to find a complementary way?

The limits of the natural sciences

Let's start with the basic stuff, the elementary particles. It was once thought that the atom was the smallest elementary particle that could not be divided into even smaller particles. We now know that is not true. The building blocks of an atom are subatomic particles such as protons, neutrons and electrons. And these are also not the real building blocks. Neutrons and protons are composed of different quarks. For the moment, that is the endpoint. But why should the quark not be composed of still a smaller particle? And why should that unknown smaller particle not be composed of an even smaller particle? And here we encounter a fundamental problem. The deeper one digs the more difficult it is to verify the underlying hypotheses empirically. What we can prove or demonstrate, even with the biggest particle accelerators, has a limit. And that limit is within reach. At the other side of that boundary one can only speculate.

What about the laws of nature? In a particularly interesting article David Albert (2012) analyzes very clearly what science can explain and what it cannot. Firstly, he notes that the origin of the laws of nature is unknown: where do these laws come from? Then he outlines the known regression problem. It is not ruled out that the truth of these laws goes back to a deeper property of nature. And why would nature stop there? Is there even a deeper underlying property? Is there a deepest property where all questions come to an end? This is a meta-question that cannot be answered with the current scientific method.

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But, he continues, though we do not know where the laws of nature come from, we do know how the laws of nature work and what their overall shape looks like. Every law of nature deals, as a general rule, with underlying elementary stuff and tries to explain its specific arrangement. In the 17th century for example, Newton supposed that the basic stuff consisted of material particles such as atoms. Physicists in the 19th century regarded both material particles and electromagnetic fields as elementary stuff. The definition of elemental stuff expanded more and more in the course of time, including quantum fields and quarks in the present day. And all the fundamental laws of nature in the past, present and future are about one thing: how this fundamental stuff is mutually *arranged*. How is the stuff organized? Which arrangements of the stuff are physically possible and which are not? How do current rankings relate to previous or next rankings? The laws of nature are about order in nature and how that order is established. But the laws do not deal in any way with the question of where the elemental stuff itself comes from. They do not deal in any way with the question of why the world consists of precisely this stuff and no other stuff, or nothing at all. So here too the explanatory power of science is subject to limits. Science tries to explain the world by using the laws of nature and elemental stuff. But science is unable to explain the origin of both laws and stuff. And indeed, to my knowledge there is no hard scientific method that deals with these problems of origin. Eventually, one ends up with heuristic methods and philosophy.

What about the development of the universe as measured by entropy? There appears to be a big problem. The Second Law which says that entropy increases until a maximum is reached applies only to the future. Living in the present one can say that the entropy of the universe has a higher value **tomorrow**. But one may not conclude that starting from the present again, the entropy of the universe was lower **yesterday**. On the basis of the underlying theory the only thing one could say is that due to the absence of limiting factors entropy always increases from the present **in both directions of time**. We cannot go into details here but the only way to save the Second Law is to assume that the entropy was very low during the Big Bang [1].

The assumption of low entropy at the Big Bang is called a boundary condition. It is based on nothing but is necessary in order to keep our theories valid. Penrose (1990) has calculated that the entropy at the time of the Big Bang was about 10^{88}, the Big Bang entropy. The universe in its present state has an entropy of about 10^{123}. That is about

billion x billion x billion x billion

higher. Thus, it is beyond doubt that the current entropy is many times higher than during the Big Bang. See figure 1A. Penrose calls the Big Bang entropy "ridiculous" low. But compared to what it could be, you should really say that this value is "ridiculously" high. It is obvious that one should start with the lowest entropy. And that value is zero. How to explain a difference between zero and 10^{88}? Compare it to opening a new bank account. If you look for the first time into the account, you expect the balance to be zero. There's no explanation needed. But if it there are billions of euros in the account, then you need an explanation. The same holds for the Big Bang entropy. What is the origin of this entropy? We do not know. The reasons for this ignorance are both practical and theoretical. First, one cannot look beyond the Big Bang. No direct or indirect observations are possible. And second, the laws of nature as we know them lose their validity. Again, one is confronted with limits beyond which statements cannot be substantiated.

Finally, we want to discuss one last issue, the problem of uniqueness. Most scientists take the occurrence of the Big Bang, 13.7 billion years ago, for granted. After that special moment the universe developed into what it is today. And if our most plausible insights are correct then the universe 'ends ' as a lifeless space without galaxies, stars and planets. Only an icy space with a few particles here and there. This state will not last a century or a million years or a billion years. It will last forever. See Figure 1B. And that makes our universe, the Big Bang and the present unique. We have learned to distrust unique phenomena if there is no plausible explanation. That is the reason why many scientists are trying to put the development of the universe in a cycle [2]. Indeed, in such a case the development of our universe is not unique. It is part of a much longer cycle. See Figure 1C. Many propositions are made. But they are all got shipwrecked on the entropy barrier. To date, there is no plausible mechanism found in which the entropy of the universe can go down. And that is a precondition for a cyclic process.

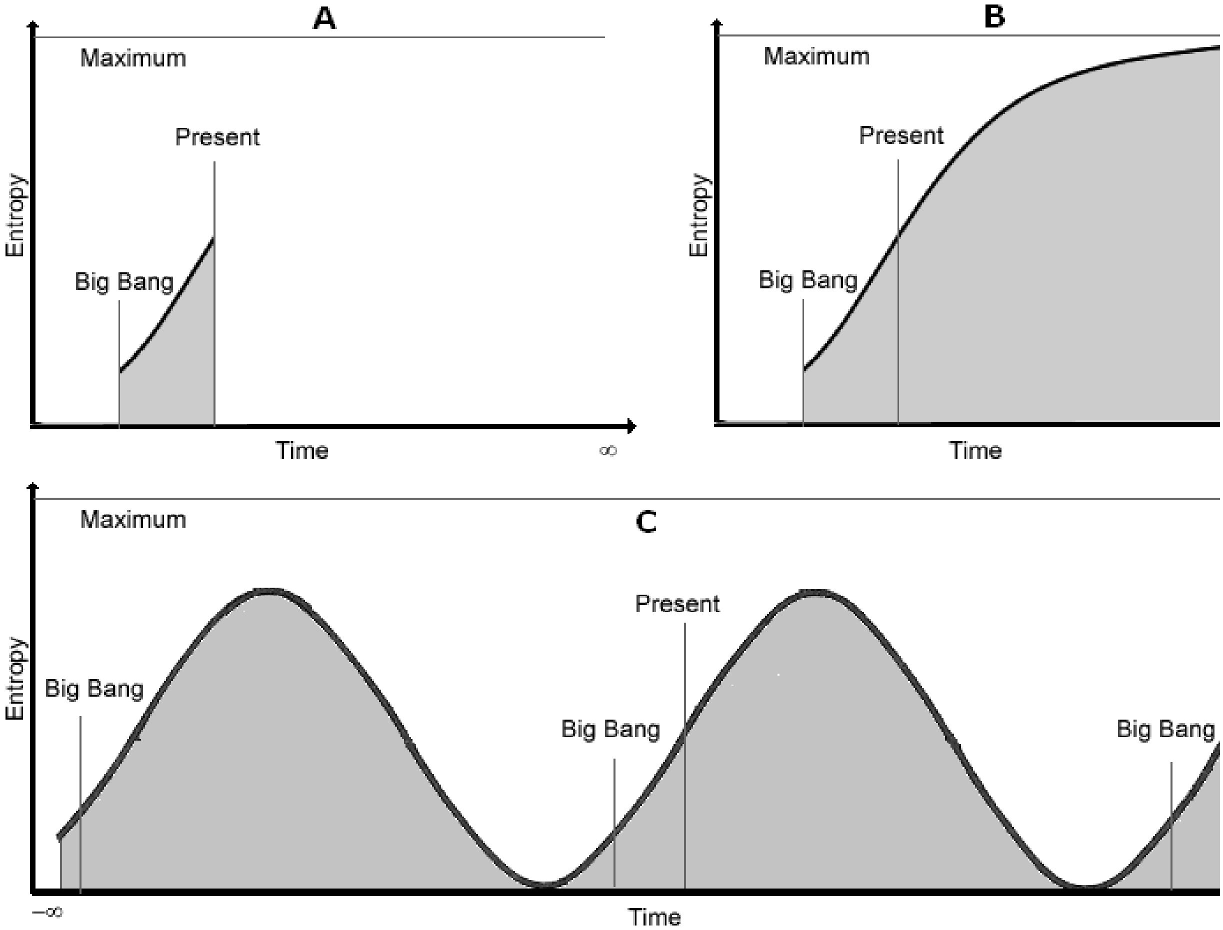


Figure 1: Entropy and time

Because the above-described problems cannot be solved through observation or theory, we follow a heuristic method.

- Which knowledge of the world can be considered as more or less unchallenged?
- Operationalize that knowledge whenever possible in a minimalist fashion
- Use these minimalistic building blocks to construct a (simulation) model or use the knowledge as a precondition.
- Check whether the results of the model shed light on these problems.

Of course the model has shortcomings. But it also gives unexpected insights that are hopefully useful to better understand the real design of the universe .

In this paper, we focus exclusively on the entropy problem: is it possible to find a plausible mechanism by which the entropy can be manipulated to go upwards and downwards so that we get a cycle? If such a mechanism can be found it would imply that our universe is not unique. It would also imply that the Big Bang is just a recurrent point in the upward cycle. And also the problem of an eternal state of maximum entropy would cease to exist.

2) Operationalization of the universe

I The universe as an isolated system.

The universe is defined as an isolated system. An isolated system is a system that has no interaction with the environment, both in the present, past and in the future. The definition implies that anything that interacts with the universe is part of it. Now, one can argue that this is not uncontroversial. A believer for example, can object that there is also such a being as God. But according to the definition this God is just inside the universe. In such a case, the universe is made up of the material universe as we know it plus God. The same reasoning applies to believers in the so-called multiverse. A multiverse consists of multiple universes that originated through a kind of evolution. There is a parent universe. That produces baby universes. Which in turn produce new baby universes, which in turn ..... All sub-universes automatically fall within the definition.

Script 1: Universe

```
function Universe() {
  this.connectionsUrn = [];
  this.nodesUrn = [];
  this.demiurge = new Demiurge();
}

Universe.prototype.init = function() {
  //Filling the nodes urn
  this.nodesUrn.length = 0;
  for(var i=0; i<input.connections+1; i++) {
    var node = new Object();
    node.N = i;
    universe.nodesUrn.push(node);
  }

  //Filling the connections urn with
  //connections to node 0
  //(any other node will do also)
  // Entropy = 0
  this.connectionsUrn.length = 0;
  for( i=0; i<input.connections; i++) {
    var connection = new Object();
    connection.N1 = 0;
    connection.N2 = 0;
    universe.connectionsUrn.push(connection);
  }
}
```

Definition 1: The universe is an isolated system.

II Elementary stuff: the bit.

The proposition that the bit is elementary is undisputed. It is not possible to divide a bit any further. It is on or off, it is yes or no, it is 1 or 0. This aspect of indivisibility led some scientists to suppose that matter particles like quarks are not elementary. They just are intermediate layers that can be reduced to bits and bit patterns. Physicist John Wheeler coined this insight with the slogan: *It from Bit*. In this vision, information underlies all material particles. Whether the latter is true, remains to be seen. Anyway, if the basis is a bit then it has to be stored somewhere. In this case, by a node that takes the values 0 or 1.

Definition 2: The universe is an isolated system consisting of nodes (in which the value of a bit is stored).

III Forces of nature: communication.

For the forces of nature to do their job, communication is necessary. Take for example the mutual attraction between two masses m1 and m2. The behavior of m1 is determined by the mass of m2 and vice versa. This mutual dependence can only be achieved by some form of communication. The minimum condition for communication is a connection between m1 and m2. Or more generally expressed: the minimum requirement for communication is a connection between two nodes N1 and N2. The connection transfers the state of N1 (0 or 1) to N2. This implies that a connection has a direction. A connection can be represented by the ordered pair (N1, N2). The mirror-image pair (N2, N1) is a different connection in which the state of N2 is communicated to

N1. Under what condition a signal is delivered will be discussed in a subsequent paper. Note that like the bit, the connection is indivisible. One cannot divide it into smaller parts.

Definition 3: The universe is an isolated system consisting of nodes and directed connections between these nodes.

IV Random behavior: demiurge

Quantum mechanics has yielded important insights. It is undisputed that the behavior of the universe at subatomic level is fundamentally random. This is operationalized by a demiurge who arbitrarily modifies the connections between nodes by means of a drawing protocol. The demiurge has no intelligence. He is only able to draw at random a connection or a node according to the urns model. We will look at it in more detail below. It should be noted that besides the lack of intelligence the demiurge has a very limited memory. His data memory is only 3 bits.

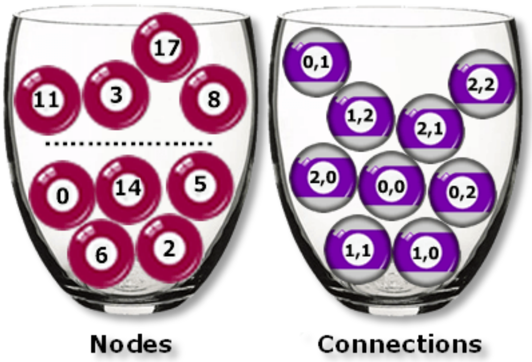


Figure 2: Urns model

Definition 4: The universe is an isolated system consisting of nodes, directed connections between these nodes and a demiurge who modifies connections at random.

Precondition 1: entropy: The entropy of the universe is expressed in bits. The value indicates the amount of information that is required to describe the topological state of the universe at any given time. It is undisputed that every system must have logical initial values. Like a new bank account starts with an initial balance of zero, the model of the universe should "begin" with entropy of zero. The entropy of our universe is zero if it consists of 1 node with N (N > 0) connections. This node is called the start node and is N times connected to itself.

Precondition 2: coherent network. Although the behavior of particles at the subatomic level is fundamentally arbitrary, the behavior of the universe on a large scale is coherent. Against this background, it seems obvious that the network of nodes and connections should also be coherent. In an incoherent network, the maximum number of nodes is two times the number of connections. In a coherent network, the maximum number of nodes equals the number of connections plus 1.

Precondition 3: there are no special nodes or connections. The simulation starts with a single node and N connections. In the script that single node was node 0. But the start node can be any other node.

Definition 4, together with the three preconditions results in script 1.

3) Operationalization of the demiurge

As mentioned before, the demiurge does not have any intelligence. He is only capable of drawing nodes and connections from urns and of modifying a connection according to a certain protocol. The protocol looks like this:

- Draw at random a connection from the connections urn to be modified;

- Draw at random from the nodes or connections urn for determining N1, the new first member of the connection;
- Draw at random from the nodes or connections urn for the determination of N2, the new second member of the connection.

Theoretically, there are 9 possible protocols. Script 2 shows the code for the demiurge including the protocols

Script 2: Demiurge

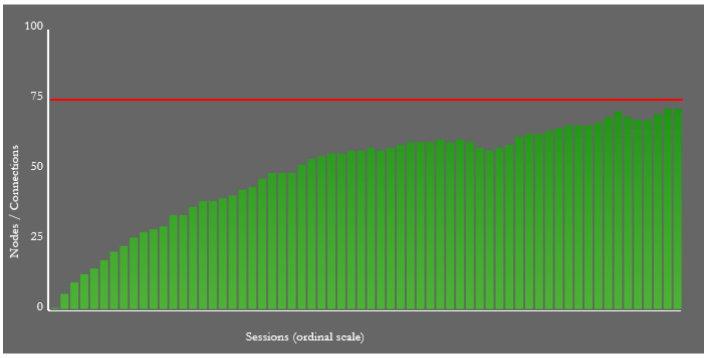
```
function Demiurge() {
  this.protocolExp = [1,4]; //Expansion protocols
  this.protocolCon = [5,6,7,8]; //Contraction protocols
  this.timer = setInterval(this.runDrawingProtocol,200); //Apply the protocol
}
Demiurge.prototype.drawConnection = function() {
  var r = Math.floor(MT.random() * universe.connectionsUrn.length);
  return universe.connectionsUrn[r];
}
Demiurge.prototype.drawNode = function () {
  var r = Math.floor(MT.random() * universe.nodesUrn.length);
  return universe.nodesUrn[r];
}
Demiurge.prototype.getProtocol = function () {
  if(input.switchExpCon == 0) //expansion)
    return universe.demiurge.protocolExp[Math.floor(MT.random() * universe.demiurge.protocolExp.length)];
  else
    return universe.demiurge.protocolCon[Math.floor(MT.random() * universe.demiurge.protocolCon.length)];
}
Demiurge.prototype.runDrawingProtocol = function () {
  var connection = universe.demiurge.drawConnection();
  var protocol = universe.demiurge.getProtocol();
```

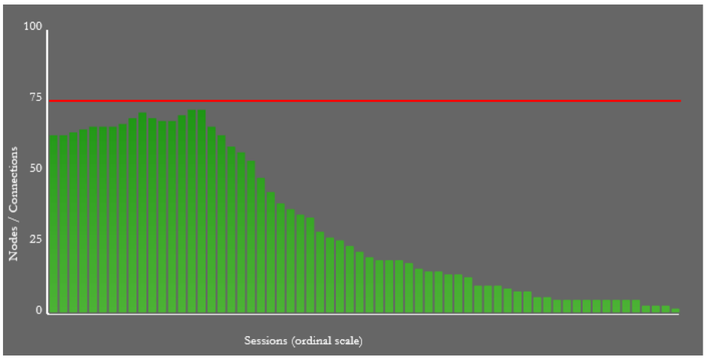
Expansion: protocol 0-4

```
  if(protocol == 0) {
    connection.N1 = universe.demiurge.drawNode().N;
    connection.N2 = universe.demiurge.drawNode().N;
  }
  else if(protocol == 1) {
    connection.N1 = universe.demiurge.drawNode().N;
    connection.N2 = universe.demiurge.drawConnection().N1;
  }
  else if(protocol == 2) {
    connection.N1 = universe.demiurge.drawNode().N;
    connection.N2 = universe.demiurge.drawConnection().N2;
  }
  else if(protocol == 3) {
    connection.N1 = universe.demiurge.drawConnection().N1;
    connection.N2 = universe.demiurge.drawNode().N;
  }
  else if(protocol == 4) {
    connection.N1 = universe.demiurge.drawConnection().N2;
    connection.N2 = universe.demiurge.drawNode().N;
  }
```

Contraction: protocol 5-8

```
  else if(protocol == 5) {
    connection.N1 = universe.demiurge.drawConnection().N1;
    connection.N2 = universe.demiurge.drawConnection().N1;
  }
  else if(protocol == 6) {
    connection.N1 = universe.demiurge.drawConnection().N1;
    connection.N2 = universe.demiurge.drawConnection().N2;
  }
  else if(protocol == 7) {
    connection.N1 = universe.demiurge.drawConnection().N2;
    connection.N2 = universe.demiurge.drawConnection().N1;
  }
  else {
    connection.N1 = universe.demiurge.drawConnection().N2;
    connection.N2 = universe.demiurge.drawConnection().N2;
  }
}
```





A design of a cyclic universe (I)

Each of the protocols 0-4 results in an expanding universe. The entropy of the system will increase until it reaches a maximum value: the Second Law in action. Each of the protocols 5-8 results in a contracting universe. The entropy of the system decreases until the value of zero is reached.
The explanation of this result is quiet simple. While applying the expansion protocols the demiurge draws at least from the nodes urn. In the initial phase of expansion, most of these nodes are free, that is to say they do not participate in a connection. Drawing a free node and putting it in a connection implies adding one degree of freedom to the system. The number of degrees of freedom of the system will therefore increase until equilibrium is reached. In the contraction protocols it works exactly the other way around. Once a node does not any longer participate in a connection, it has no possibility to come back into the network. To give an example. In the first step, the demiurge randomly draws a connection, say (5,10). Then, the connection nodes are overwritten using a particular protocol. This results for example in the connection (8,12). If the original connection (5,10) is the only one in which node 5 participated, then node 5 will disappear from the network. And this deletion process continues until only one node remains.

	Protocol 1		Protocol 2		Protocol 3		Protocol 4		
Nodes with N connections	**K1 Out %**	**K2 In %**	**K3 Out %**	**K4 In %**	**K5 Out %**	**K6 In %**	**K7 Out %**	**K8 In %**	**K9 Poisson %**
0	36.7	45.7	37.0	99.9	99.9	36.1	45.4	38.0	36.8
1	36.2	27.1	37.0	0.0	0.0	37.6	27.9	35.1	36.8
2	19.6	14.9	18.2	0.0	0.0	19.1	15.4	18.8	18.4
3	5.9	8.2	5.6	0.0	0.0	5.3	7.0	6.3	6.1
4	1.6	2.9	1.9	0.0	0.0	1.7	2.9	1.2	1.5
5	0.1	1.0	0.3	0.0	0.0	0.3	0.7	0.6	0.3
6	0.0	0.2	0.0	0.0	0.0	0.0	0.6	0.1	0.1
7	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>= 9	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Entropy in bits per node	1.85	1.96	1.87	0	0	1.85	1.96	1.88	1.87

Table 1: Simulation results. Connections = 1.000; Drawing sessions = 500.000.

Are all protocols equally suitable? Of the five expansion protocols the first one drops out because it results in an incoherent network. And that violates precondition 2. The table below shows some simulation results for the remaining four expansion protocols in a universe with 1,000 connections. The outcome demonstrates that the protocols 2 and 3 also fail. The result of protocol 2 (K4) shows 999 nodes having no incoming connections. All **incoming** connections stay attached to the start node. Something similar can be seen in Protocol 3 (K5). All **outgoing** connections remain stuck at the start node. And that makes the start node special. All nodes have a chance to be deleted from the network except the start node. And that is contrary to the third precondition. Simulation of the 4 contraction protocols does not show any particularities. We do see that the last node after contraction is an arbitrary node. This terminal node is the start node of the new expansion.

We now have 2 expansion protocols and 4 contraction protocols. There is no tentative preference for a certain expansion or contraction protocol. That means that to expand the universe, the demiurge applies randomly one of the protocols 1 and 4. To contract the universe he applies one of the protocols 5 to 8. The reader can play with the simulation model here:

Manual version: "www.communsens.com/design of a cyclic universe/1/entropyswitch.html".

4) To a cyclic universe

Start value: number of connections.

The scripts of the universe and the demiurge show that the system is not yet completely isolated. To get the system to work, it is required to input the number of connections (input.connections). In order to obtain a cyclic universe, it is necessary that someone or something flips the switch (input.switchExpCon) at the demiurge. In order to satisfy the requirement of an isolated system, both inputs should be generated within the system with as little intelligence (code) as possible. To start with the first one. It is logical to assume that, where everything is random, the start value is also a random value. The only restriction is that the number of connections is at least one and not infinitely large [3]. Such behavior is easy to incorporate in the model. For example:

Script 3: Turning points auto version

```
//Called from runDrawingProtocol before and after connection
changed
Universe.prototype.updateNodesData = function (c,i) {
  universe.updateNodeData(c.N1,i);
  universe.updateNodeData(c.N2,i);
}
//Keep track of the number of connection per node;
Universe.prototype.updateNodeData = function (n,i) {
  var node = universe.nodesUrn[n];
  node.conn += i;
  if(i==1 && node.conn == 1)
    universe.nodesInNetwork++;
  else if(i==-1 && node.conn == 0)
    universe.nodesInNetwork--;
}
//Called after connection changed from runDrawingProtocol
Universe.prototype.turningPoint = function () {
  //universe in contraction mode
  if(universe.demiurg.switchExpCon == 1) {
    if(universe.nodesInNetwork == 1) {
      //draw random number for connections
      universe.connections = Math.round(MT.random() * 50)+ 50;
      universe.init();
      //go to expansion mode
      universe.demiurg.switchExpCon = 0;
      return true;
    }
  }
  //universe in expansion mode
  else if(universe.nodesInNetwork >= .74 *
      (universe.connections+1)) {
    //go to contraction mode
    universe.demiurg.switchExpCon = 1;
    return true;
  }
  return false;
}
```

```
universe.connections = Math.round(MT.random() * 50) + 50;
```

In the model, the universe itself draws a random number of connections which in this example is a number between 50 and 100 (inclusive). A next question is to what extent an initial value of say 50 differs from an initial value of say 100. Are the costs of 100 connections not higher than the costs of 50 connections? That is not the case because the entropy remains zero: a node with 50 connections has the same entropy as a node with 100 connections. One can also approach this problem from a more classical viewpoint. The relationship between energy and entropy can be derived from Boltzmann's Distribution Law [4]:

Change in Energy = Change in Entropy x Temperature.

It follows that the choice of the number of connections is not an energetic problem. Because the entropy does not change, no change in energy will occur.

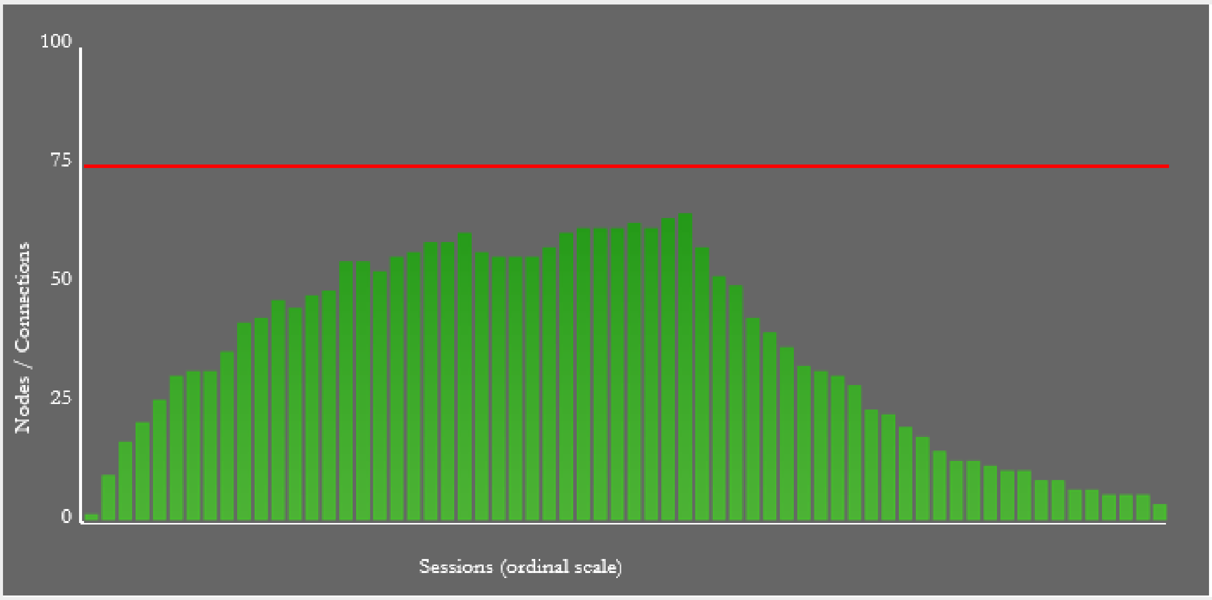
Entropy switch: turning points

The foregoing provides a good handle to select the first turning point namely at the end of the contraction phase if the number of nodes in the universe equals one. In that state, it does not matter whether the universe consists of a hundred or a billion connections. At this turning point a random number of new connections is drawn. The switch is then pulled and the universe goes from contraction to expansion with the new number of connections.

The turning point at maximum entropy is much more difficult to formulate. Maximum Entropy is not an absolute value but a stochastic variable that fluctuates around a certain level. On the basis of the simulations, we know approximately when the entropy of the system is maximal namely as the number of nodes in the network that do not participate in a connection is about 26% of the total. On the basis of the simulations, we also know when the start node loses its last connection. It happens usually after maximum entropy is reached. One can now formulate two alternative turning points:

a) Turn the switch when the start node is no longer connected;
b) Turn the switch as the number of nodes in the network reaches 74% of the total.

Theoretically, the first alternative might look best. After all, it means that the system cannot have a memory of its origin. In the manual simulation, alternative (a) is used as stop criterion. In the auto version, alternative (b) is applied due to practical considerations (the cycles go faster).



Auto version: "www.communsens.com/design of a cyclic universe/1/entropyswitch_auto.html".

5) Discussion

Maxwell's demon

The physicist Arthur Eddington wrote the following in 1927:

"The law that entropy always increases holds, I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations — then so much the worse for Maxwell's equations. If it is found to be contradicted by observation — well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

This statement, although perhaps a bit exaggerated, shows the importance of the Second Law. And for a reason. All constructions to reduce the entropy of an isolated system such as the universe have failed. One of the nicest examples is called Maxwell's demon.

Entropy in thermodynamics is equivalent to the entropy we use in this paper, the Shannon entropy of information theory. Both can be expressed in bits. This similarity makes it possible to explain why Maxwell's Demon cannot violate the Second Law. The Dutch Wikipedia describes the thought experiment as follows.

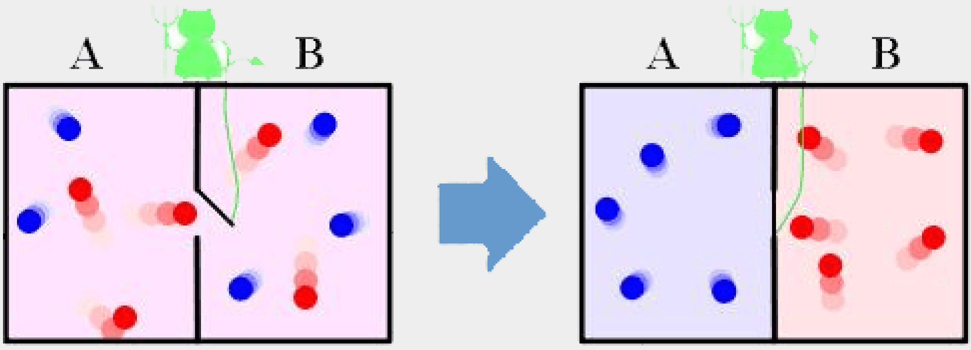


Figure 3: Maxwell's demon

Figure 3 shows two spaces, with a partition, which together form a closed system. Both spaces contain the same gas at the same temperature, but in the partition there is a door that can be operated by a being, Maxwell's demon. Suppose now that this being has the possibility to determine the velocity of a molecule, then it can open the door for a molecule with a high speed and close the door for a molecule with low speed. In this way, the demon would, for example, admit molecules with a high speed in the right-hand space. This would mean that the average speed of the molecules increases in this space, and thus increasing the temperature of the gas in that space. The mean velocity of the molecules in the left-hand space decreases, so the temperature drops there. This creates a temperature difference between the two areas. The result is that the entropy decreases. But this is contrary to the Second Law of Thermodynamics. Which says that entropy always increases in our world.

"Now, it is true that the entropy of the gas can be lowered, but the demon has to make a decision each time on the basis of the velocity of the molecule that comes along. The information about the previous molecule is still in its memory, so at some point in time his memory will be completely occupied. ... The decrease of the entropy of the gas expressed in terms of bits, which can be achieved by an ideal demon, is exactly equal to the memory capacity of the demon. So there is less information needed to specify the microstate of the gas but just so much more information is needed to specify the memory state of the demon. Erasing the memory is not an option, because this increases the entropy of the environment with at least the same amount." Thus, in the most favorable case, the entropy will remain the same.

And here's the fundamental difference between Maxwell's Demon and our demiurge. Where the demon 'smuggles' bits from the gas to his memory, the demiurge has a data memory of a couple of bits. The reduction of the entropy is achieved only by a change in protocol from [1,4] to [5,6,7,8].

Within this model of the universe the Second Law has two formulations:

- Expansion phase: the entropy of an isolated system that is not in equilibrium increases with time, until the maximum for that system is reached.
- Contraction phase: the entropy of an isolated system decreases with time, until the minimum of zero is reached.

Matthew Effect

Traditionally, networks with a complex topology are described by the random graph theory of Erdos and Rényi (1960). According to this theory the probability that a node in a random network has N connections follows a Poisson distribution. As can be seen in Table 2, this applies only to that portion of the expansion protocols where the demiurge draws from the nodes urn (K1, K3, K6 and K8). If drawn from the connections urn one gets different distributions. Characteristic of these last distributions is the fact that the number of nodes without a connection is relatively large, on average about 45%. On the basis of the Poisson distribution the expected percentage is around 37%. This difference can be explained by the so-called Matthew Effect. This effect is named after a parable from the Gospel of Matthew:

For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken even that which he hath.

In short, the rich get richer and the poor get poorer. And that is exactly what occurs when the demiurge draws from the connections urn. Suppose an arbitrary node has by change a relatively large number of ingoing and / or outgoing connections. The probability that the demiurge draws a connection in which that node participates is therefore relatively large. The result is that such a node even gets more connections. Protocol 1 favors the rich with lots of incoming connections (K2). Protocol 4 favors the rich with many outgoing connections (K7).

The Matthew Effect is not just a nice theoretical phenomenon but it occurs quite often in reality. The best known example is the topology of the Internet. In 2000 there were about one billion web pages (nodes) that were connected by an average of seven hyperlinks (connections). But some pages had only one incoming link, while others, like the Wikipedia, had millions. In order to explain this specific structure a variant of the Matthew Effect was applied: a page with many incoming links attracts more new incoming links than a regular page. This is broadly in line with our protocol 1. And it proved very useful: the topology of the Internet came pretty close to the theoretical expectation.

Nodes with N connections	Out %	In %	In / Out %	Age as % sessions
0	41.9	41.7	25.1	---
1	32.3	32.4	25.0	1.5
2	15.6	15.7	18.5	2.3
3	6.2	6.6	12.6	2.6
4	2.5	2.4	7.7	2.9
5	1.1	0.8	4.7	3.1
6	0.3	0.3	2.8	3.4
7	0.1	0.1	1,6	3.3
8	0.0	0.1	1.0	3.7
>= 9	0.0	0.0	1.0	4.3
Total	**100.0**	**100.0**	**100.0**	**2.3**
Entropy in bits per node	1.95	1.95	2.69	

Table 2: Simulation results. Protocol [1,4]. Connections = 10.000; Drawing sessions= 2.000.000.

The Matthew Effect is of great importance for the robustness of a network. It favors cluster formation (hubs) and allows some forms of self-organization. Purely by chance large clusters occur that are followed by smaller clusters, and these in turn by even smaller ones, etc. This hierarchy ensures that the network is to a large extent error-proof. If failures occur randomly and the great majority of the nodes have a limited number of inbound links, then the chance that this affects a hub is negligible. Even as a hub falls to disorder, the network will not lose its connectivity because of the remaining hubs.

Table 2 shows the Matthew Effect in the network at a state of maximum entropy and using expansion protocol [1,4]. Around 42% of the nodes do not have any outgoing connection. A similar percentage has no inbound connection. The expected percentage on the basis of the Poisson distribution is only around 37%. The Matthew Effect is significant. This is also reflected in the average age of a node. A node is "born" at the moment that it participates for the first time in a connection. The node 'dies' when it loses its last connection. The average age, as a percentage of the number of sessions of, nodes with at least one incoming or outgoing connection is 0.023. Expressed in trekking sessions that is 0.023 x 2,000,000 = 46,000 sessions. This corresponds to the average of a node with 2 connections. Roughly one can say that the age of a node is proportional to its connectivity. Conclusion: even at maximum entropy, there are complex structures (based on the number of connections), which live longer than simple structures. This will be discussed in more detail in a subsequent article.

A design of a cyclic universe (I)

Scale-free network

All simulations suggest that the network in the expansion phase tends towards a scale-free distribution [5]. That means that the probability distribution in Table 2 is independent of the size of the network. Inputs of 100 or 1,000 or 10,000 connections show a similar Matthew distribution. We did not succeed in tracing this distribution to an existing theoretical distribution. From the simulation results it is evident that it is not a Poisson distribution. Barabasi and Albert (1999) propose a power function. Such a function gives good results for networks with a high average number of connections per node. The tail of the power function is then quite similar to the appearance of clusters. However, at an average of 1, this power function does not perform well.

The information content of the universe

The information content of a given universe corresponds to the number of nodes in the network which have at least one connection. The simulation results in Table 2 show that the number of nodes in the network in this variant amounts to (1-.251) x 10,000 = 7,490. The information content of this universe is 7,490 bits.

How much information is needed to describe that universe? In Table 2, we see that in order to describe the **outgoing** connections 1.95 bit per node is required. A total of 19,500 bits. There is also 1.95 bit per node needed in order to describe the **ingoing** connections or 19,500 bit. To describe the complete microstate of the universe both entropies should be added [6]. So to reproduce the universe in Table 2, 39,000 bits of information is needed. Given that the information content of the universe is only 7,490 bits, then the universe is not able to describe itself. Even if the universe is not in a state of maximum entropy this statement is valid. It implies that there cannot exist an entity in such a universe that is "omniscient." A prerequisite for omniscience in this situation is information content of at least 39,000 bits. And a content of 7,490 bits comes not even close.

One may wonder whether the demiurge in this model is 'omnipotent', almighty. After all, after some time, each node and each connection passed his hands. However, the concept of "might" implies a purpose for which it is used. But the demiurge does not have a purpose. He is just the representation of a blind and random process.

6) Summary

Assumptions & preconditions

The paper describes a heuristic method that models a cyclic universe. The model is based on 4 assumptions. These assumptions are, in our opinion, more or less unchallenged. They are operationalized in the most minimal form:

- The universe is an isolated system.
- The bit is postulated as elemental stuff. It is indivisible and is represented by a node that can take the value 0 or 1.
- The forces of nature can only work if there is communication. The most basic form of communication occurs in a connection between two nodes. Such a connection is elementary and cannot divide further.
- The universe displays at the deepest level random behavior. This behavior is operationalized by a demiurge who modifies connections according to a certain drawing protocol.

A design of a cyclic universe (I)

Additionally there are three preconditions:

- The entropy of the universe must have a logical start value. This value is zero.
- The network is coherent
- There are no special nodes or connections.

These assumptions and conditions result in a very simple simulation model with two inputs: the number of connections for the start situation and the state of a switch which determines which drawing protocol the demiurge applies.

Theoretically, there are 9 drawing protocols. Of these, 3 drop out because they are contrary to the preconditions. What remains are two protocols that result in an expanding universe with increasing entropy and four protocols that result in a contracting universe with decreasing entropy. As a final step, the two inputs are generated from within the model so that the system is truly isolated.

What has been shown

What has been shown is that the entropy in this isolated system can be manipulated by changing the protocol by which the demiurge modifies connections. A combination of these protocols results in a cyclic universe.

What is further demonstrated is that - in spite of the random behavior of the demiurge - there is a form of self-organization in the network. The structure of the expansion protocols triggers the so called Matthew Effect. Even at a level of maximum entropy the network is relatively more populated by complex structures (measured by the number of connections) than by simple ones.

Finally, it is shown that a state of "omniscience" is impossible. The information content of the model universe is much lower than the information that is needed to describe its state. Within this universe an entity who is omniscient cannot occur.

Open questions

There are plenty of them. To name the four most important ones:

- Where is the physical stuff? Although relatively complex information structures in the network do occur, it does not imply that they reflect the physical reality. How can one make a plausible step from information structure to particle physics?
- Where are the laws of nature? The laws of nature are about the arrangements of elementary stuff in time. And they work in a consistent way, anywhere, anytime. It the current model it is unclear where these laws reside. But one thing is certain, they cannot come from outside the isolated universe. If there are laws of nature, and they really are, then their definition and operation should be located in the structure of the universe. But how should we imagine that?
- Where's the Math? The greatest scholars have wondered why the laws of nature are caught with such a great precision by mathematical formulas. Does mathematics precede the laws of nature? And if so, where do we find the math in this design of this universe?
- What is the meaning of time? The current model suggests that "time" existed before the Big Bang. Is that correct? And what about the arrow of time in a contracting universe?

In Part II we will discuss these questions. We also want to see whether this heuristic approach provides insight into the three hottest topics of the moment: gravity, dark matter and dark energy.

Notes

[1] For a good and understandable introduction to this problem, see Penrose (1989) and Green (2004)

[2] For an interesting discussion of the possibilities see Carroll (2010)

[3] The interesting case of a universe with zero connections will be discussed in a following paper.

[4] Boltzmann's distribution law:

$$\frac{W_2}{W_1} = \frac{e^{-E_2/kT}}{e^{-E_1/kT}}$$

indicates that the probability that a system is in a certain state is proportional to $e^{-E/kT}$, where E is the energy of the configuration and T is the Temperature of the system. This equation leads to the relation between the change in energy and the change in entropy. See De Dios (2008): http://bouman.chem.georgetown.edu/S02/lect22/lect22.htm

[5] Application of separate protocols 1 and 4 results in about 45 % nodes without input or output connection . In joint application [1,4] this percentage drops to around 42 %. In all cases, however, the results remain stable (apart from random fluctuations) regardless of the number of connections.

[6] If one does not distinguish between ingoing and outgoing connections then the entropy is 2.96 bit per node.

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