Editors' Notes: We welcome Peter Baker's inclusion in the *Journal of Space Philosophy* his beyond universe musings about the unknown. He generated a dialogue among some of the Journal's members of the Board of Editors that will lead to more extensive future discussion on his thoughts. ***Bob Krone and Gordon Arthur*.**

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Recursive Distinguishing

By Joel D. Isaacson and Louis H. Kauffman, April 28, 2015

Dear Editor,

This letter is an advance statement about a paper that we (Joel Isaacson and Lou Kauffman) are in the process of writing. The work we are about to present is based on our mutual collaboration and is founded in the original work of Joel Isaacson[8] on recursive distinctions and the structure of character strings and on the work of Louis Kauffman[9] on recursion and distinction in cybernetics and in relation to the work of George Spencer-Brown.[10]

Everyone who works in science, mathematics, or computer science is familiar with the fundamental role of the concept of distinction and the making of distinctions in both theory and practice. For example, Einstein's relativity depends on a new distinction between space and time relative to an observer and a new unification of space and time that is part and parcel of this distinction. Every moment of using a digital computer

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[8] Joel D Isaacson, "Autonomic String-Manipulation System," U.S. Patent No. 4,286,330, Aug. 25, 1981, www.isss.org/2001meet/2001paper/4286330.pdf; Joel D Isaacson, "Steganogramic Representation of the Baryon Octet in Cellular Automata." Archived in 45th ISSS Annual Meeting and Conference: International Society for the System Sciences, Proceedings, 2001, www.isss.org/2001meet/2001paper/stegano.pdf; Joel D Isaacson, "The Intelligence Nexus in Space Exploration," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone (Toronto: Apogee Books, 2006), Chapter 24, thespaceshow.files.wordpress.com/2012/02/beyond_earth-ch24-isaacson.pdf; Joel D Isaacson, "Nature's Cosmic Intelligence," *Journal of Space Philosophy* 1, no. 1 (Fall 2012): 8-16, bobkrone.com/sites/default/files/Nature%e2%80%99s%20Cosmic%20Intelligence%20%20By%20Joel%20Isaacson,PhD.pdf.

[9] Louis H Kauffman. "Sign and Space," in *Religious Experience and Scientific Paradigms: Proceedings of the 1982 IASWR Conference* (Stony Brook, NY: Institute of Advanced Study of World Religions, 1985), 118-64; Louis H Kauffman, "Self-reference and recursive forms," Journal of Social and Biological Structures 10 (1987): 53-72; Louis H Kauffman, "Special Relativity and a Calculus of Distinctions," Proceedings of the 9th Annual International Meeting of ANPA (Cambridge: APNA West, 1987), 290-311; Louis H Kauffman, "Knot Automata," Proceedings of the Twenty-Fourth International Conference on Multiple Valued Logic – Boston (Los Alamitos, CA: IEEE Computer Society Press, 1994), 328-33; Louis H Kauffman, "Eigenform," *Kybernetes* 34, no. 1/2 (2005): 129-50; Louis H. Kauffman, "Reflexivity and Eigenform – The Shape of Process," *Kybernetes* 4, no. 3, (July 2009): 121-37; Louis H Kauffman, "The Russell Operator," Constructivist Foundations 7, no. 2 (2012): 112-15; Louis H Kauffman, "Eigenforms, Discrete Processes and Quantum Processes," *Journal of Physics, Conference Series* 361 (2012): 012034; Marius Buliga and Louis H Kauffman, "Chemlambda, Universality and Self-Multiplication," in *Artificial Life 14 – Proceedings of the Fourteenth International Conference on the Synthesis and Simulation of Living Systems*, ed. Hiroki Sayama, John Rieffel, Sebastian Risi, René Doursat, and Hod Lipson (Cambridge, MA: MIT Press, 2014).

[10] George Spencer-Brown, *Laws of Form* (London: Allen & Unwin, 1969).

depends upon the myriad of distinctions that are handled automatically by the computer, enabling the production and recording of these words and the computation and transmission of information. Distinctions act on other distinctions. Once a new distinction is born, it becomes the object of further action. Thus grows all the physics that comes from relativity and thus grows all the industry of computation that grows from the idea and implementation of the Turing machine, the programmed computer.

And yet it is not usually recognized that it is through *recursive distinguishing* that all such progress is made. We will discuss recursive distinguishing both in its human and its automatic aspects. In the automatic aspect we will give examples of automata that are based on making very simple distinctions of equality, right/left, that then, upon allowing these distinctions to act on themselves, produce periodic and dialectical patterns that suggest what are usually regarded as higher-level phenomena. In this way, and with these examples, we can illustrate and speculate on the nature of intelligence, evolution, and many themes of fundamental science.

We give here an example of recursive distinguishing that is based on recursively rewriting strings of symbols where we use the special set of symbols {D, <, >, *} and can begin with any string of typographical symbols. The recursion is based on distinguishing the neighbors of a given character in the string. So if C is a character in the string S, we produce a string S' such that the end-points of the new string S' are unchanged and:

1 C' = < if C has a copy of C as a right-hand neighbor, but a different left-hand neighbor.
2 C' = > if C has a copy of C as a left-hand neighbor, but a different right-hand neighbor.
3 C' = * if both the right- and left-hand neighbors are equal to C.
4 C' = D if both the right- and left-hand neighbors of C are different from C.

Thus if S = * A B *, then S' = * D D * and S'' = * < > * and S''' = * D D *. This is a simple period two pattern. Now consider S = * ABA *. Then we have S' = * DDD *, S'' = * < * > *, S''' = * D D D * and again a period two pattern. But now examine Figure 1, and we see that there is a period three pattern for S = * A B A B *:

ABAB
DDDD
*<**>*
D<>D
DDDD

Figure 1: Period Three.

In Figure 2, we show a Mathematica program that instantiates these rules. In Figures 3 and 4, we show examples of higher periods.

```
    ZZ = “ * A B R A C A D A B R A * ”;
w = StringSplit[ZZ];
LL = Length[w]
Print[ StringJoin @@ w];
ww = w;
For[i = 0, i < 20,
    For[j = 2, j < LL,
        ww[[j]] = “D”;
        If[ w[[j]] == w[[j - 1]], ww[[j]] = “>”, ];
        If[ w[[j]] == w[[j + 1]], ww[[j]] = “<”, ];
        If[ w[[j - 1]] == w[[j]] && w[[j]] == w[[j + 1]], ww[[j]] = “*”];
        j++];
    w = ww;
    Print[ StringJoin @@ ww];
    i++]
```

Figure 2: A Mathematica Program for the Recursive Discriminator

```
*ABABABAB*
*DDDDDDDD*
*<******>*
*D<****>D*
*DD<**>DD*
*<>D<>D<>*
*DDDDDDDD*
```

Figure 3: Period Five

```
*ABABABABABABABAB*
*DDDDDDDDDDDDDDDD*
*<**************>*
*D<************>D*
*DD<**********>DD*
*<>D<********>D<>*
*DDDD<******>DDDD*
*<**>D<****>D<**>*
*D<>DDD<**>DDD<>D*
*DDD<*>D<>D<*>DDD*
*<*>DDDDDDDDDD<*>*
*DDD<********>DDD*
*<*>D<******>D<*>*
*DDDDD<****>DDDDD*
*<***>D<**>D<***>*
*D<*>DDD<>DDD<*>D*
*DDDD<*>DD<*>DDDD*
*<**>DDD<>DDD<**>*
*D<>D<*>DD<*>D<>D*
*DDDDDDD<>DDDDDDD*
*<*****>DD<*****>*
*D<***>D<>D<***>D*
*DD<*>DDDDDD<*>DD*
*<>DDD<****>DDD<>*
*DD<*>D<**>D<*>DD*
*<>DDDDD<>DDDDD<>*
*DD<***>DD<***>DD*
*<>D<*>D<>D<*>D<>*
*DDDDDDDDDDDDDDDD*
```

Figure 4: Period 27.

The remarkable feature of these examples of recursive distinguishing is their great simplicity coupled with the complexity of behaviors that can arise from them. Notice that each successive string in the recursion can be regarded a*s describing* its predecessor. It is remarkable that there should be such intricate structure in the process of description. Description is another word for making a distinction. The description of a given string is a string of individual distinctions that have been made. Each individual distinction is one that recognizes whether a given character in a string is equal to a left neighbor, a right neighbor, both, or neither. This elementary distinction becomes instantiated as a character in the new description string. The description string can be subjected to the same scrutiny and so the recursive process continues.

Note that this recursive process depends, at its base, on the most elementary distinctions possible for character strings. No mathematical calculations are performed. We should mention that distinction-making without mathematical computation is ubiquitous in natural neuronal processing. Joel Isaacson's collaboration with Eshel Ben-Jacob includes attempts to demonstrate RD in live neuronal tissue.[11] One can also point to the molecular interactions of DNA and RNA as natural RD automata. Finally, we can point to the notion of chemlambda computation of Buliga and Kauffman[12] as an abstract chemical combination computing that includes aspects of lambda calculus, but is based on direct and local action related to distinctions inherent in the system.

All these matters will be discussed in more detail in the longer paper. Note that in the RD system we use in this letter, the action is taken on the entire string before replacing it with a new string. Thus it is the distinctive structure of the string as a whole that is being described.

The epistemology behind this automaton is based directly on distinctions that can be made automatic. Other cellular automata are also based on distinctions. For example the well-known Wolfram line automata[13] are based on character strings with only two characters and the recognition of the eight possible triples of characters that can occur, including characters to the left and to the right of a given character. The automaton rule then replaces the middle character according to the structure of this neighborhood.

There is a crucial difference in epistemology between a Wolfram line automaton and our recursive distinction program. We do not replace according to an arbitrary rule. We place a character that describes the distinctive structure of the neighborhood of the predecessor character. *Our automaton engages in a meta-dialogue about its own structure.* This dialogue is then entered as a string for the automaton to examine and act upon once again. The patterns produced by this recursive distinction are part of a dialogue that the strings hold with themselves.

One can ask many questions about recursive distinguishing as presented here. The automaton we have demonstrated illustrates a concept that can be instantiated in many ways. We hope, in the paper to come, to demonstrate Turing universality for automata of this type. But in fact we feel that the paradigm of recursive distinguishing goes beyond the paradigm of the Turing machine, and we will discuss that issue as well.

There is another level to our automaton and *that is the level of examining with human eyes and minds* the output of the automaton, seeing patterns in the whole collection of strings and engaging in further design on this basis. This is where the recursive automatic distinctions meet the aware distinctions of the observers of the system, connecting the automatic with the aware process and design level that goes on in the larger network of science. We will stop here with our letter. We intend to discuss all these issues in more detail in our longer paper.

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[11] Personal communication.
[12] Buliga and Kauffman, "Chemlambda."
[13] Stephen Wolfram, "A New Kind of Science," (Champaign, IL: Wolfram Media, 2012).