MORE ON THE MATHEMATICS OF RULE-BOUND SYSTEMS

PAUL BALLONOFF

Ballonoff Consulting Service
Washington, DC USA

Much systems theory evolved from analysis of physical or biological systems. But rule-bound systems analysis was initially developed from the somewhat unusual starting place of the mathematical analysis of cultures. This paper therefore discusses several examples which show that rule-bound systems are also systems in the more classical sense. This is done by discussing mathematical or formal results in two areas of work: evolutionary systems and cognition.

The reason one can identify a particular culture as being *that* particular culture is that each culture is unique. This has often led researchers to conclude that therefore a culture cannot be analyzed at all, except perhaps as a literary object. The theory of rule-bound systems, as laid out in Ballonoff (1987, 1994), has instead argued that although it is true that each culture is unique, that does not prevent analysis. Instead, the rules systems of the culture are subject to analysis. This paper argues that the analysis thus found is similar to analyses common in other areas of research (e.g., Conrad, 1983, 1988; Ezhkova, 1992; Manna & Pnueli, 1992). It is an object of systems research to discover such common properties.

Previously, for example, it was pointed out that the rule structure of a culture system resembles the rule structure of a class of computer programs called the operating system and therefore that the technical

Address correspondence to Paul Ballonoff, Ballonoff Consulting, Fifth Floor, 1899 L Street, N.W., Washington, DC 20036.

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subject called temporal logic of concurrent operating systems was also a theory of human rule-bound systems (Ballonoff, 1994; Manna & Pnueli, 1992). This paper explores other formal analogies.

Rule-bound systems can be related to classical automata theory. This can be most easily seen by comparisons of rule-bound theory to the work on the mathematics of structural programmability of biologically evolving systems, as developed by Conrad (1983, 1988). In biological organisms, the "rules" of the organism are embodied, at least in part, in the genes of the organism. In general, the less complex the organism, the greater is the degree of its activity that is directly programmed genetically. Complex multicellular organisms that also have brain systems (such as humans) are more able to choose actions.

Conrad analyzed these issues by defining three notions of programmability. The first of these is that "A program in the strict sense is a rule that (when embodied) generates the behavior of a system, subject to the condition that the rule is of a finite type" (Conrad, 1988; p. 287). The analogy could not be more plain. Also note that all rules previously discussed by the theory of rule-bound systems are certainly finite.

Next Conrad defined "effective programmability" as follows: "A real system is (effectively) programmable if it is possible to communicate desired programs to it in an exact manner (without approximation) using a finite set of primitive operations and symbols" (Conrad, 1988, pp. 287–288). Superficially, this definition is also met by human rule-bound systems, because all systems discussed in Ballonoff (1987, 1994) are actual human systems that use languages to communicate rules. The definition is strictly met by the human marriage rule systems described mathematically by various authors, cited in Ballonoff (1994). The definition is somewhat less clearly met when we consider that although human languages do, at any moment, probably use a "finite set of primitive operations and symbols," such languages are not considered always to communicate "in an exact manner (without approximation)," although certainly most legal systems at least seek to do this.

Finally, Conrad also states that "A physical system is structurally programmable if it is effectively programmable and if its program is mapped by its structure" (1988, p. 288). At first sight, this definition seems to preclude all human cultural systems, because they are not "physical." But that would be a false inference: humans are indeed physical, and their relations with each other are indeed real. The essential problem with deciding whether human rule systems are structurally programmable is in deciding whether "its program is mapped by its structure."

The possibly surprising answer is that, in at least some cases, this is almost certainly so, and in at least some others the human system and its environment form the physical structure used for mapping the rules. If one does not believe this, consider the example of riddles. Riddles are analogies using natural experience or relationships among humans to pose and solve cognitive problems. Riddles are not rules, as such, but their existence in their common form using natural objects and relationships as analogies (Austerlitz, 1958) proves the existence of cognitive structures that meet the criteria for structural programmability. The idea that human cultures can and do map their cultural rules through analogies to relationships among natural objects, animals, and humans was explored in great depth in many well-known works by the social anthropologist Claude Levi-Strauss. The similar notion that human cultures use human body parts and their interconnections and functions as analogies for cultural structure has been developed by Douglas (1982).

Cultural studies are often seen as trivial compared with "hard sciences" because of their subject matter, but the preceding citations and conclusion show that the opposite is the case. Cultural systems are in fact physical systems or, at least are structurally programmable in certain important ways. This being the case, it should also be possible to reach conclusions about structurally programmable systems that also apply to human rule systems. This is also true, and indeed examples of this were used and cited in Ballonoff (1994).

To realize that such analogies are possible, consider a brief summary of the properties of systems analyzed by Conrad: "a computing system cannot at the same time have high programmability, high computational efficiency, and high evolutionary adaptability" (1988, p. 285). Human rule systems that attempt to map all actions of each individual by defined rules tend to fail (as witnessed by various recently demised totalitarian states) or to survive only where their physical environments were also stable for long time periods (such as in pre–Western contact Australian aboriginal cultures). Only where the system of rules permits more flexibility do the same sets of rules tend to survive as the physical or technological environment changes.

This description of how a culture operates is similar to Ezhkova's (1992) mathematical framework for a self-teaching artificially intelligent machine that uses its own experience to construct analogical rules of interpretation. Human cultures construct themselves in much the same way: use of experience to create patterns for prediction. The foregoing references show how this is done in at least some human systems based on naturally occurring relations as the basis for the analogies. Indeed, Ezhkova gives an example of how a particular control device was constructed using her methods. The device measured internal temperatures and conditions of a physical system and represented this to the system operator by using images of an ocean in various states and colors.

The importance of these various observations to viewing human cultural rules as part of classical systems theory cannot be overstated. The papers by Conrad (1983, 1988) show that structurally programmable systems are Turing machines. This conclusion alone is sufficient to show that study of rule-bound systems is properly part of the subject matter of systems analysis. Thus other conclusions in Conrad (1983, 1988) about properties of biological evolution, or in Ezhkova (1992) and Manna & Pnueli (1992) about logics of operating systems, can also be usefully studied for parallel results in description of human rule-bound systems.

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