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DYNAMICAL JURISPRUDENCE: LAW AS A
COMPLEX SYSTEM

Gregory Todd Jones*

Vast flocks of English starlings gather over the roost at dusk and
glide through the air in a spectacular display of spatial coherence.¹
Both the evolutionary, or ultimate cause, of flocking behavior, and
the proximate mechanisms that makes this performance possible are
still relatively poorly understood.² Flocking, along with schooling in
fish³ and swarming in insects,⁴ was until recently believed to be
driven by one or more leaders, whose followers percolated the
behavior through the group. We are now beginning to discover that
this collective behavior results not from leadership, but emerges from
individuals following simple sets of local rules.⁵

Highly multidisciplinary teams of scientists from anthropology,
biology, computer science, ecology, economics, physics, political

¹ For an excellent resource summarizing an European Union study of starling flocking for the
purpose of employing complex systems principles to shed light on collective animal behavior, including
dramatic video footage and still photographs, see http://angel.elte.hu/starling/index.html (last visited
Mar 23, 2008).

² See generally, Michele Ballerini, et al., An Empirical Study of Large, Naturally Occurring
Starling Flocks: A Benchmark in Collective Animal Behaviour, ANIMAL BEHAVIOUR (forthcoming,

³ See generally, Yoshinobu Inada & Keiji Kawachi, Order and Flexibility in the Motion of Fish

⁴ See generally, ERIC BONABEAU, SWARM INTELLIGENCE: FROM NATURAL TO ARTIFICIAL
SYSTEMS (1999).

⁵ Indeed, recent work has demonstrated that three simple local rules can capture essential flocking
behavior:

1. Separation: steer to avoid crowding local flockmates.
2. Alignment: steer towards the average heading of local flockmates.
3. Cohesion: steer to move toward the average position of local flockmates.

For a web site that includes a simulation allowing experimentation with these rules, an excellent
summary of the relevant theory, and an exhaustive catalog of resources related to collective group
movement, see http://www.red3d.com/cwr/boids/ (last visited mar 23, 2008). For another simulation of
this behavior, with access to the underlying code, see URI WILENSKY, NETLOGO FLOCKING MODEL,
CENTER FOR CONNECTED LEARNING AND COMPUTER-BASED MODELING, NORTHWESTERN
science, psychology, mathematics, sociology, and numerous other fields have begun to recognize that large systems of interacting heterogeneous agents often display very complex behaviors that cannot be easily deduced by studying the behaviors of the individual agents. Lessons from these emergent collective behaviors are now being applied to help us rethink the dynamics of human behavior.

Wouldn't it be worthwhile if we could identify and understand individual human behaviors that result in dramatic human group behavior – and use this understanding to optimally design institutions that constrain this behavior in ways that promote social welfare?

A close examination of the dynamics of forest fires reveals that the extent of damage is closely related to the density of the trees. This is not particularly surprising. However, computer simulations reveal that this observation offers more nuance. Holding other variables such as combustibility, rainfall, etc. constant, computational results show that a fire started on one end of an artificial forest with 57% density would typically result in about 10% of the forest burning before the fire burned itself out. The same artificial forest with 60% density would result in more than 75% of the forest destroyed.


10. These models are stochastic and results reported are typical averages over a series of simulation runs.

11. Clearly, there are many more variables that may affect outcomes and these damage percentages are not intended to be accurate estimates. The simulations are intended to show differences in outcomes relative to each other and to demonstrate the isolated non-linear effect of density.
What this exercise demonstrates, that may not be immediately obvious, is that a very small increase in density results in a dramatic increase in forest burned. The relationship between density and destruction is a highly non-linear one.

Wouldn’t it be worthwhile if we could understand this non-linearity and take its possibility into account when designing regulation?

Thomas Schelling, the 2005 Nobel Laureate in Economics, and one of the first to apply emergence and nonlinear dynamics to questions of public policy, used a checkerboard to demonstrate that a small preference for similarity with neighbors could lead to disproportionately large levels of segregation. Today, we are fortunate to have computers to replicate Schelling’s studies and, much like the forest fires described above, simulations demonstrate a non-linear relationship between preference for similarity and emergent segregation. And much like the flocking starlings discussed above, Schelling’s systems of interacting heterogeneous agents display segregation behavior that cannot be derived from the individual preferences for similarity.

Some of our recent work in the Consortium on Negotiation and Conflict Resolution’s Computational Laboratory for Complex Adaptive Systems takes agents from Schelling’s chessboard and presents them with a cooperative task in a complex social network.

13. Id.
14. Id.
15. See Figure One. Complex social network architectures allow for agents with a wide range of interaction partners, not artificially limited by the adjacent squares on a checkerboard, a toroidal, two-dimensional, non-bordered space. Our simulations also differ from Schelling’s in that agents are engaged in a cooperative task rather than being limited to merely making decisions about moving to satisfy preferences for similarity. See Gregory Todd Jones & Travis Lloyd, Parents Involved in Community Schools v. Seattle School District No. 1 et al.: Computational Models of Prejudice and the
Because agents can be identified by some arbitrary tag (here, their color), it is possible for agents to employ prejudicial strategies – treating agents with a different color differently than they treat agents with their same color.

We have shown that when the level of segregation is controlled exogenously, by an institution such as the law, the success of prejudicial strategies increases – and social welfare decreases – as segregation increases. More precisely, the success of prejudicial

Contact Hypothesis (unpublished working paper, available from authors); Gregory Todd Jones & Travis Lloyd, Computational Models of Prejudice Reduction: Spatial Robustness and the Contact Hypothesis (unpublished working paper, available from authors).
strategies increases sharply, in a steep, nonlinear relationship to increasing segregation.\(^{16}\)

Figure Two: The Relative Success of Prejudicial Strategies (Percentage) and Cooperation (Percentage) as a Measure of Social Welfare as Functions of Levels of Segregation (full color diagram available at: http://www.gregorytoddjones.com/publications.htm).

One possible consequence of these characteristics is that decisions such as the Supreme Court's *Seattle School District v. Parents Involved*,\(^{17}\) while expressly seeking to merely limit segregation plans may essentially eviscerate *Brown v. Board of Education*\(^{18}\) by virtue of emergent nonlinearities.

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16. See Figure Two. These steep s-shaped curves often indicate what is known as “phase transitions,” where small changes, or perturbations, to system variables can bring about large scale changes in system properties.


Wouldn’t it be worthwhile if law makers and the courts understood emergence and nonlinearity well enough to consider their possible consequences in their decision making?

There is a small, but growing cadre of legal scholars who do think that it would be worthwhile to consider the implications of networks, complex systems, and nonlinear dynamics to the future of the law.19 The breadth of current substantive applications is impressive, including jurisprudence,20 law and economics,21 torts,22 criminal law,23 environmental law,24 regulatory law,25 bankruptcy,26 mediation

19. We would be in good company—it has been suggested that the study of networks, complex systems, and nonlinear dynamics has pervaded all of science. See Steven H. Strogatz, Exploring Complex Networks, 410 NATURE 268 (2001).


and other forms of alternative dispute resolution, administrative law, capital markets, telecommunications, legislative and judicial decision making, discrimination and equal opportunity, constitutional law, business law, land use law, intellectual


property, and political theory – and this is surely not a complete list.

In this Symposium edition of the Georgia State University Law Review, we are fortunate to have contributions from many of the pioneers in the application of complex systems and dynamical systems theory to the law. J.B. Ruhl, one of the first legal scholars to apply complexity theory to his work, sets the stage by inviting us to think about the law as a complex system. To aid those for which this is a new enterprise, Ruhl provides a primer of complex systems principles and suggests how certain characteristics of the law may be complex, in the technical definition of the term. Particularly valuable is Ruhl’s taxonomy of complex systems principles paired with tangible examples from legal systems. Finally, Ruhl considers what the implications may be for legal system design when the law is conceived as a complex adaptive system.

Next, along with collaborators Doug Yarn, Reidar Hagtvedt and Travis Lloyd, I use evolutionary game theoretic simulation models to explore the influence of structure in complex social networks where pro-social, welfare optimizing behavior is possible, but not assured. It has been widely demonstrated that social capital, or social “connectedness,” matters in these contexts. We show that the distribution of social capital also matters by exerting a negative influence on pro-social behavior that is shown to be statistically independent from average social capital. We conclude by suggesting that institutions, including legal institutions, designed to promote

39. I am grateful to J.B. Ruhl for his web site, Complex Adaptive Systems Literature for Law and Social Sciences, hosted by the Society for Evolutionary Analysis in Law, where many of the above citations were discovered. His bibliography is regularly updated and can be found at http://law.vanderbilt.edu/seaVresources/readingscomplex.htm (last visited Mar 23, 2008).
homogeneity in social capital may produce increases in social welfare overall, and as such, is properly thought of as a collective good.

Daniel Katz and Derek Stafford, political scientists from the University of Michigan, employ a subset of tools from complexity science, those of network analysis, to examine how the decision making of individual judges may map to the judiciary’s aggregate doctrinal output. 42 Katz and Stafford hypothesize that the decision making framework used by any particular jurist to interpret and apply sets of legal rules is impacted by a combination of jurists who are socially prominent and socially proximate. Their work is at once an excellent introduction to network architecture and analysis and an eerie look into the doctrinal connections within the federal judiciary. Using the path of judicial clerks as a proxy for proximity, they paint a picture of complex networks that make sense on their face and make former law clerks anxious to discover their own place in the links of federal jurisprudence. The real power of the network approach is revealed when they reorganize the networks by demographics such as the party of the appointing president revealing sometimes surprising relationships that may have otherwise remained hidden.

In general, complexity theory principles call for the emergence of co-evolved institutions from the interactions of agents following simple local strategic rules. Relying on micro-level mechanisms similar to Adam Smith’s “invisible hand” which produces optimal prices from the bottom up merely from the interactions of individuals pursuing their own interests, proponents of deregulation argue that top-down intervention is unnecessary to create efficient markets. Barbara Cherry brings decades of telecommunications policy expertise to bear in crafting her warning that the sustainability of critical communications infrastructures will depend on the existence of specific top-down legal rules. 43 Framing her discussion with the


principles of complex systems, Cherry sets out certain institutional boundary conditions that will be necessary to maintain emergent properties of widespread availability, affordability and reliability.

Bernard Trujillo leads us on a deeply philosophical exploration of the nature of modeling in the social sciences. He is critical of what he sees as a long standing reliance on linear models with a stochastic term added as a place holder for our ignorance. Trujillo advocates replacing these conventional random terms with others that may be supplied by the mathematics of complexity. He suggests that nonlinear chaotic systems may be used to successfully model complex social forms, like the diffusion of legal doctrine, and brings his theory to bear on two examples that define much of his other substantive scholarship: finance and bankruptcy law.

Finally, Ted Blumoff, an ethicist and legal philosopher, employs a social network analysis to examine the nature of the action-omission network in the criminal law. Blumoff begins with Hume's understanding that humans have a feeling of obligation to others that radiates outward from themselves resembling a network with valence that tends to attenuate as the connections become more remote. He argues that omission accountability is a function of relationally proximate networks with proximity being a function both of biology and fiduciary relationships.

These papers embody significant breath both in analytical tools and substantive application and as suggested earlier represent but a small sample of the growing cadre of legal scholars putting complexity science principles to work in their research. As J.B. Ruhl concludes, the goal shared by this work is to make visible legal system machinery that remains hidden when examined through the dominant lens of linearity. The recognition of complex attributes, such as nonlinearity and their consequences, is a start, but much

remains to be done before complex systems theory can offer tangible guidance for institutional designers. Within the institution of the law, we hope this Symposium edition is seen as a step in that direction.