Unsettling the Centralized Mindset

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Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds.

Researchers in the field of adaptive behavior are quite familiar with the idea of higher-order complex global patterns emerging from the lower-level simple local interactions of components in a distributed system. Our artificial ants form colonies and self-organized foraging expeditions; our robots and simulated birds flock and cooperate on tasks; our genetic algorithm populations form species spontaneously; and our neural network and subsumption architectures work to create intelligent navigation and exploration. But to most people, these sorts of ideas remain unfamiliar and counterintuitive. Instead, the typical reaction when seeing organized behavior in a group of individuals (be they ants, plants, or people) is to assume that there is a leader directing the activities of each group member, or that there is some organizing structure such as a food patch already present in the environment. How can we overcome these centralist tendencies and help people to appreciate self-organized emergent behavior where it exists? For several years now, Mitchel Resnick has been thinking about the origins and implications of the centralized mindset, and devising ways of educating people to overcome this mindset and see emergent phenomena in a new, distributed light. His new book, Turtles, Termites, and Traffic Jams, presents an overview of his research on these issues. At the same time, Resnick provides insights into self-organization and decentralization that will be enlightening even to those already working in this area. This book is important reading for all of us interested in communicating our research on complex emergent behavior to others both inside and outside our field, and for everyone wishing to share in the excitement of understanding behavior in a new way, a feeling of discovery that is evident throughout the pages of this work.

Resnick’s stated goals are to understand the qualitative ways people think about the behavior of self-organizing systems--their "folk systems science"--and to develop ways of opening up that thinking to a new, decentralized point of view. The most effective means Resnick sees for helping people come to grips with paradoxes such as how a mind can emerge from a collection of mindless parts, or how an ant colony can forage so skillfully without a central leader, is to have people design, build, and observe the behavior of distributed systems of their own. To this end, he has created a massively parallel programming language, StarLogo, in which simulations of systems of many individuals interacting in an active environment can easily be written. Resnick has introduced many people to the workings of decentralized systems through this new version of the

NOTE: \textbf{\textit{text}} means to make "text" bold; \textit{\textit{text}} means italic.
traditional Logo language. In the central portion of his book he takes us on a tour of the ideas of self-organization and emergent behavior as seen through the eyes of high-school students (and himself) while developing models of particular phenomena.

The variety of systems expressible in the relatively simple and easy-to-use language of StarLogo is impressive. Even more exciting (for readers and the students described alike) is the leverage this language provides for seeing complex behaviors emerge in a population of "turtles" from very few lines of code specifying the actions of each individual turtle and region of the environment. Through a simple program that models the aggregation of distributed slime-mold individuals into large clusters, we learn about the effects of positive and negative feedback. Termites piling up wood chips into larger (and sometimes smaller) stacks demonstrate the emergence of stable structures. Plan-like behavior surprisingly appears in the way an ant colony explores its environment and exploits the discovered food sources in increasing order of distance from the nest. The same colony’s behavior also shows the importance of symmetry breaking in choosing between two equidistant food supplies, rather than spreading itself thin by going for both at once. Trapped states (absorbing boundary conditions) are easily understood in terms of a population of turtles in a simple ecology going extinct when it hits zero individuals, and the connection can be quickly drawn to the same thing happening when one of the termites’ wood chip piles dwindles to nothing. Parallel constraint satisfaction in forming circular patterns, critical thresholds in spreading forest fires, and recursion for growing organic patterns are all also readily captured in the StarLogo framework. The overall picture that emerges is one in which positive feedback processes act to amplify small random initial fluctuations and thereby break symmetries, resulting in increasing differentiation of structure in parts of the system, until critical thresholds are passed and states are trapped finally to form more or less stable self-organized end configurations.

One of the important aspects of this book for researchers studying adaptive behavior is Resnick’s emphasis on the crucial role of the environment. He stresses that the environment is an active participant in StarLogo simulations, capable of almost as much independent behavior at each location as the turtles themselves. Patches in the environment can grow substances, spread gradients, affect the turtles, and self-organize on their own. As a result, the environment becomes "a character, not just a background setting" (p. 44). Understanding the structure of the environment thus proves essential for understanding the structure of the turtles’ collective emergent behavior, a sentiment that is gaining increasing acceptance.

Overcoming the centralized mindset, even with the help of experiencing powerfully evocative StarLogo simulations, can be an uphill battle, because this way of thinking is so deeply entrenched. As Resnick points out, even Marvin Minsky, the champion of decentralized theories of mind, had trouble recognizing the self-organizing aggregation of slime molds. Understanding the origins of this mindset can help in moving beyond it, so Resnick asks why it has been with us for so long, and why it is breaking down in many domains, from biology to economics to politics, at the present time. He believes that much of our expectation of centralized design and control is learned, through exposure to the centrally designed human artifacts and patterns that surround us, and through experience of hierarchically controlled social and political structures. Both of these sources of bias can be overcome by new learning about distributed systems.
But the centralized mindset may go even deeper than that--it may arise from an evolved set of heuristics for dealing with important aspects of the world that are inherently centralized, caused by localized features of the world, or controlled by individuals. Food and water often do occur in clumps in the environment, and our ancestors in the Pleistocene savannah could have used gatherings of animals (or plants) as a reliable indicator of an underlying attractive local resource. The movements of herds of gazelles or flocks of ducks would not have been as important to focus on as the route of the single animal being hunted, one at a time. And knowing one’s position in the social dominance hierarchy, and paying attention to the immediate intentions and behaviors of the individuals higher up in the hierarchy, clearly could be of use for one’s continued comfortable survival. In some ways, Resnick’s book is about the breakdown of decentralization--how centralized structures, clusters, hierarchies, or plans can emerge from an initially dispersed, unorganized state. For survival purposes, it is probably most important to understand the end-state of these systems, where things have become clustered and organized. To this end, a centralized mindset is most adaptive. But with a new goal, a new viewpoint becomes necessary: Scientific understanding of these phenomena at a deeper level requires a decentralized mindset, to fathom how these initially distributed systems began and became as they now are.

Educational methods that recognize and deal with both learned and evolved centralized biases will be most effective in helping people move to the decentralized point of view. Analyzing our biases may even suggest paths of least resistance for change: For example, the most complex, distributed, interactive systems we have had experience with (whether learned within a lifetime or evolved across generations) may well be social systems, including the interpersonal politics of families, inheritance, marriage, and the like. If this is the case, then introducing concepts of distributed self-organizing systems by way of social/familial examples might be most natural. Such analyses could also indicate the best time to introduce decentralized concepts. Again, if social structures are the best introduction to distributed systems, then this introduction might be most effective in teenage years and later, when social relationships become the focus of attention; younger children might remain oblivious and harder to reach with such concepts (as Resnick, in fact, indirectly indicates).

Resnick writes very well (he has a background in journalism), and his use of case studies of students creating and learning about decentralized systems makes for an enticing learning experience for the reader as well. Examples of the StarLogo code used to create the systems in the book are provided throughout. While this book is certainly not meant to be a tutorial on StarLogo itself, and some of the routines can be difficult to follow completely, for the most part they are very readable, and add to the appreciation of the simplicity that can generate complexity at a higher level. Resnick states that he is more interested in the stimulation of new ways of thinking than in accurate simulation of specific processes in nature, but the StarLogo programs in action are so compelling that one must be careful to remember not to overgeneralize their behavior to the behaviors of the real systems after which they are modeled. That is, drawing the line between qualitative and quantitative ways of thinking about the modeled system can be tricky: For instance, do foraging ants really go back and forth on the trail to the same food source they have previously visited, as written into the StarLogo model, or can they switch to other trails? How would this affect symmetry breaking for exploiting multiple food sources, qualitatively or quantitatively? Happily, if one wants to be more precise about such modeling issues, the StarLogo code is easily changed, and interactive investigation can answer these kinds of questions very quickly. Finally,
information about where to obtain StarLogo (and an index!) would be useful\(^1\), and even more pictorial examples of the simulations (for those without StarLogo) would be interesting, but these are minor quibbles.

Overall, Resnick's research and this book provide a provocative look at the use of "microworld construction kits" for changing the way people think about the (macro)world. But this is just the beginning, as Resnick admits; much remains to be done in developing new educational methods and furthering the understanding of distributed system behavior. In particular, Resnick (personal communication) feels that the next step should be to seek a better integration of centralized and decentralized viewpoints: In what situations does one approach have advantages or disadvantages relative to the other? What governs the evolution of decentralized organization into centralized and back again? Are such shifts peculiar to human organizations (businesses, political entities, etc.), or do they occur elsewhere in nature? How can we integrate centralized and decentralized structures into the systems we design? These two viewpoints are not right or wrong, Resnick reminds us, but rather are alternatives that may be more or less appropriate levels of description in different situations. By fostering the decentralized alternative in the face of the centralized mindset bias, Resnick has done much to increase the tools at our disposal for understanding the behavior of systems around us, and to decentralize our ways of knowing the world.

\(^1\) A Macintosh version of StarLogo should be available for distribution in summer, 1995. Contact Mitchel Resnick directly for more information, at mres@media.mit.edu.