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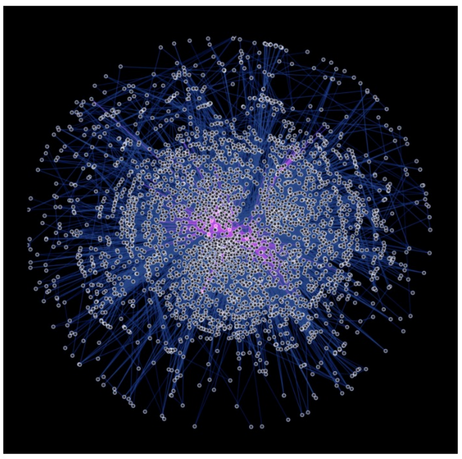
Mathematically Modeling the Rise of Innovation

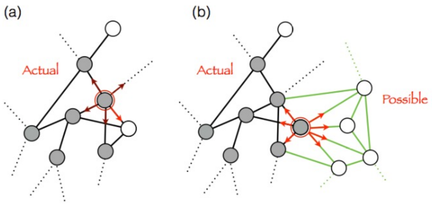
A quick look at the work of physicist Vittorio Loreto.



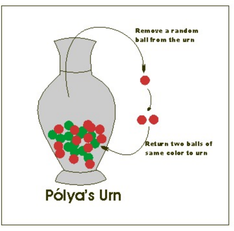
Excerpted from Last Week in the Future V18.0: The most interesting news in IoT, AI, and other tech fields from last week. If you like our content, please sign up for the newsletter here.

Adam Grant gave us insight into innovations from a social-science perspective in his book Originals: How Non-Conformists Move the World. Now Vittorio Loreto gives us insight into innovations from a mathematical perspective, providing a model that captures the patterns of innovation.

Loreto's study follows the work of S.A. Kauffman who introduced the notion of "adjacent possible": all things one step away from what already exists can arise from incremental modifications.



Adjacent possible is hard to model. Unexplored possibilities (white nodes in the graphic above) include unexpected and dynamically changing events. Despite these complexities, Loreto et al. have found a predictable and even measurable pattern to innovation.



Loreto's paper starts out with a model called Polya's Urn. It models a rich-get-richer phenomenon as the probability of selecting the same colored ball increases after a ball is withdrawn at random (see graphic above). This model, however, does not account for unexpected possibilities and cannot explain the sublinear growth of Heaps' law.

Heaps' law predicts the rate at which novelties happen. Concretely, Heaps law applies to innovations in language: the rate in which new words appear and old terms die out. It turns out that there is a sublinear relationship where the corpus of words of size *n* is proportional to *beta* values between 0.4 and 0.6.

Another important law, Zipf's law, models the frequency distribution of the explored regions (gray nodes). Zipf's law applies to how edits appear on Wikipedia. In the English language, the most frequent word (*the*) occurs about twice as often as the second most frequent word (*of*). We knew of these empirical patterns before, but we did not understand why these patterns form until Loreto et al. created their mathematical model.

The model developed by Loreto et al. includes unexpected events. Named "Polya's Urn with Innovation Triggering," the rules are as follows: after drawing a new ball, if the color has been seen before, you return other balls of the same color. If the color is new, then balls of entirely new colors are added to the urn. This model corresponds to the phenomenons explained by Heaps' and Zipf's Laws. It has been validated with how we make edits on Wikipedia or discover novelties (new song, books, etc).

Put simply, the value of Loreto et al.'s work is that a mathematical model for innovation allows us to better understand the requisite conditions, ultimately helping us to teach and drive innovation across industries. Loreto himself best summarized the implications of his research:

> *By providing the first quantitative characterization of the dynamics of correlated novelties, these results provide a starting point for a deeper understanding of the adjacent possible and the different nature of triggering events (timeliness, spreading, individual vs. collective properties) that are likely to be important in the investigation of biological, linguistic, cultural, and technological evolution.*

If you'd like to read more, check out the full paper: Dynamics on expanding spaces: modeling the emergence of novelties.