The Scaling Laws of Human Travel – A Message from George

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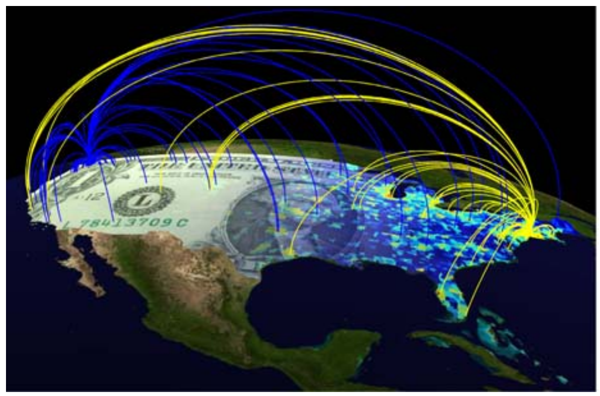
Short time trajectories of individual dollar bills that were inititally reported in Seattle (blue) and New York (yellow). Lines connect the initial entry location and the location where the bill was reported less than a week after inital entry.

Dispersal is the key driving force of various spatiotemporal phenomena on geographical scales. It can synchronize populations of interacting species, stabilize them, and diversify gene pools. Human dispersal in particular is responsible for the geographical spread of infectious agents and the spatial dynamics of diseases. In the light of increasing international trade, intensified human traveling, and imminent emergent infectious diseases the knowledge of dynamical and statistical properties of human dispersal is of fundamental importance and acute. Despite its crucial role, a quantitative assessment of human dispersal remains elusive. We will report on a quantitative assessment of human travel on geographical scales by investigating the circulation of individual dollar bills in the United States[1]. Our analysis is based on data collected at the Internet bill-tracking game www.wheresgeorge.com. The idea of the game is simple: a large number of banknotes is marked by a player and brought into circulation. If another person receives a marked banknote, she can register its current location online and return the bill into circulation. Since wheresgeorge.com started more than 50 million dollar bills have been registered and approximately 10 million have been reported again.

Based on a dataset of over a million individual displacements we found that the dispersal of dollar bills is anomalous in two ways. First, the distribution of traveling distances decays as a power law, indicating that the movement of individuals is reminiscent of superdiffusive, scale free random walks known as Lévy flights. However, computing the time for an initially localized ensemble of dollar bills to redistribute equally within the United States, we found that this time is much longer than predicted by the simple Lévy flight picture.

A deaper analysis of the temporal aspects of the dataset showed that the probability of remaining in a small, spatially confined region for a time T is dominated by algebraically long tails as well. This property, which typically yields subdiffusive dispersal competes with the superdiffusive impact of long jumps and attenuates superdiffusive dispersal.

We show that dispersal can be described on many spatiotemporal scales by a two parameter continuous time random walk model to a surprising accuracy. We conclude that dispersal is an ambivalent effectively superdiffusive process.

Existing models for the geographic spread of infectious diseases can now be checked for consistency with our findings and a new class of models for the spread of epidemics can be conceived which are based on our results.

1. Brockmann, D., Hufnagel, L. & Geisel, T. The scaling laws of human travel. Nature 439, 462-465 (2006).