How Knowledge Propagates? A Fractal Model Justified on the Example of the Out of Eden Walk

Octavio Lerma[1,2], Leobardo Valera[2],
Deana Pennington[2], and Vladik Kreinovich[1,2]
[1]Computational Science Program
[2]Cyber-ShARE Center
University of Texas at El Paso, El Paso, TX 79968, USA
lolerma@episd.org, leobardovalera@gmail.com,
ddpennington@utep.edu, vladik@utep.edu

1. Outline

- Most quantitative models of knowledge propagation use a system of differential equations.
- In such models, after a certain period of time:
  - the number of new people getting a certain knowledge (or acquiring a certain skill)
  - decreases exponentially with time.
- Experiments show that sometime, a slower "fractal" power law describes knowledge propagation better.
- In this talk, we analyze which model is better.
- As an example, we use responses to Out of Eden Walk dispatches.
- In this project, a Pulitzer Prize-winning journalist Paul Salopek reports from different locations.
- This example confirms the fractal model.

2. Formulation of the Problem

- To improve teaching and learning, it is important to understand how knowledge propagates.
- Traditional knowledge propagation models are based on diff, equations – similar to epidemics propagation.
- In these models, for large times t, the number of new learners decreases as $r(t) \approx A \cdot \exp(-\alpha \cdot t)$.
- Some empirical data suggests that this decrease follows the power law: $r(t) \approx A \cdot t^{-\alpha}$.
- Power laws are ubiquitous in real life.
- These laws underlie *fractal* techniques pioneered by B. Mandelbrot.
- In this talk, we check which model is better.

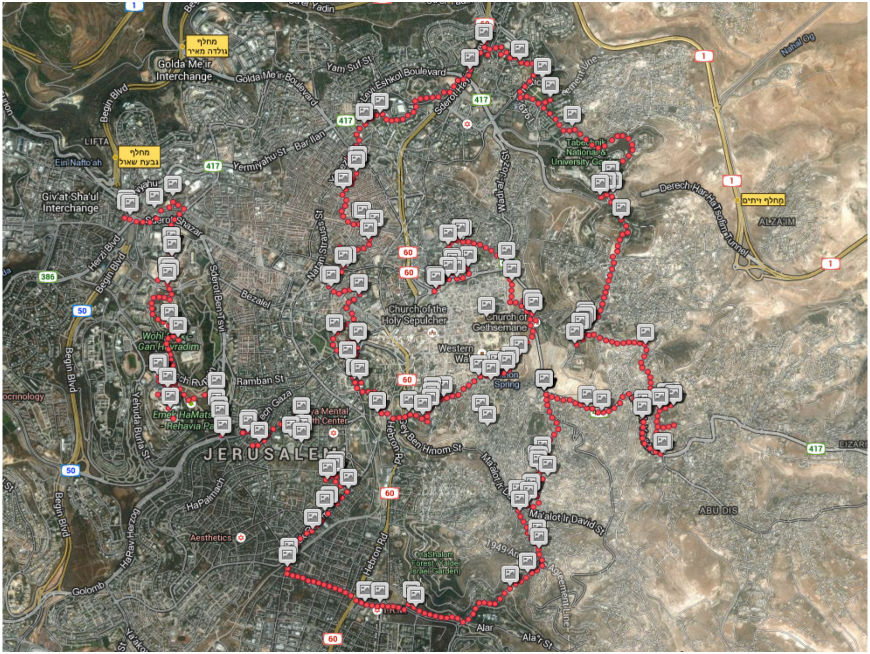
3. Out of Eden Walk Project: A Description

- Commenced on January 10th, 2013 in Ethiopia.
- The Out of Eden Walk is a 7-year, 21,000 mile long, storytelling journey created by Paul Salopek.
- Paul Salopek is a two-time Pulitzer Prize winning journalist.
- This project is sponsored by the National Geographic Society.
- Reports from this journey regularly appear:
  - in the National Geographic magazine;
  - in leading newspapers: NY Times, Washington Post, Chicago Tribune, Los Angeles Times, etc.;
  - on the US National Public Radio (NPR).

4. The Journey Starts in Ethiopia

5. The Journey Starts in Ethiopia (cont-d)

6. Walking Through Jerusalem



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7. It Is Not Only About Beauty of the Faraway Lands: Refugees

8. This Project Has Important Educational and Knowledge Propagation Goals

- Main objective: to enhance education and knowledge propagation as main features of journalism.
- Main idea: *slow journalism* – revealing human stories and world events from the ground, at a walking pace.
- The project has largely succeeded in this goal:
  - the website has thousands of followers worldwide,
  - there are also many Facebook and Twitter followers;
  - over 200 schools worldwide regularly use Salopek's reports to teach about world's cultures.

9. Out of Eden Walk Project: Technical Details

- After visiting an area, Paul Salopek publishes a *dispatch* describing his impressions and thoughts.
- As of now, there are more than 100 dispatches.
- Followers are welcome to add comments after each dispatch.
- After two weeks, each dispatch gathers from 15 to more than 250 comments.
- These comments are part of the knowledge propagation process.
- We trace how the number of comments made by the readers changes with time.
- This number reflects how the knowledge contained in a dispatch propagates with time.

10. Power Law Model vs. Traditional Approach

- In the power law model, the number of comments $r(t)$ decreases with t as $r(t) = A \cdot t^{-\alpha}$.
- This model has two parameters: A and $\alpha > 0$.
- Traditional models use differential equations:

$$\frac{dr}{dt} = -f(r).$$

- When $r = 0$, we have $f(r) = 0$.
- The simplest function $f(r)$ with $f(0) = 0$ is linear: $f(r) = \alpha \cdot r$.
- For this $f(r)$, we already get a 2-parametric family of solutions $r(t) = A \cdot \exp(-\alpha \cdot t)$.
- So, we compare power law with this exponential model.

11. How We Compare: Technical Details

- How the number of comments $r(t)$ depends on time t?
  - exponential model: $r(t) \approx r_0(t) = A \cdot \exp(-\alpha \cdot t)$;
  - power law model: $r(t) \approx r_0(t) = A \cdot t^{-\alpha}$.
- To check which model is more adequate, we use the chi-square criterion

$$\chi^2 \stackrel{\text{def}}{=} \sum_t \frac{(r(t) - r_0(t))^2}{r_0(t)}.$$

- To estimate A and α, we use both Least Squares $\sum_i e_i^2 \to \min$ and robust (ℓ^1) estimation $\sum_i |e_i| \to \min$.
- Result: the power law is more adequate:
  - for exponential model H_0, $p \ll 0.05$, so H_0 is rejected;
  - for power law model H_0, $p \gg 0.05$, so H_0 is not rejected.

12. Comparison Results

Dispatch Title	N_c	χ^2_p	$\chi^2_{p,1}$	χ^2_e	p_p	$p_{p,1}$	p_e
Let's Walk	271	30.6	30.0	31,360	0.33	0.37	0.00
Sole Brothers	61	22.1	22.8	83	0.76	0.74	0.00
The Glorious Boneyard	59	16.3	18.6	262	0.96	0.91	0.00
The Self-Love Boat	67	63.1	60.0	124	0.00	0.00	0.00
Go Slowly–Work Slowly	91	33.0	31.5	821	0.24	0.29	0.00
The Camel and the Gyrocopter	52	28.4	24.6	72	0.45	0.65	0.00
Lines in Sand	69	21.4	18.3	89	0.81	0.92	0.00

13. Conclusions

- To improve teaching and learning, it is important to know how knowledge propagates.
- Traditional models of knowledge propagation are similar to differential-equations-based models in physics.
- Recently, an alternative fractal-motivated power-law model of knowledge propagation was proposed.
- In this talk, we compare this model with the traditional model on the example of the Out of Eden Walk project.
- It turns out that for the related data, the power law is indeed a more adequate description.
- This shows that the fractal-motivated power law is a more adequate description of knowledge propagation.

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