A Glider For Every Graph

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The Challenge!

• Rotationally-invariant, straight-line motion across a discrete medium
  – A pattern that can move in any direction
  – An algorithm that doesn’t change with angle

• A medium that behaves like space
  – Should support relativistic curvature
  – Should be flexible and dynamic
  – Should have no preconceived orientation
The Motivation

• What’s the payoff?
  – A simple approximation to a physical particle
  – A step towards a discrete, deterministic, Turing-Machine-equivalent model of nature

• Why describe motion specifically?
  – Starting point for analyzing physical systems

• Why rotational invariance in a dynamic medium?
  – That’s what we see
Overview

• What others have done
• What I have done
  – Choice of medium
  – A pseudo-particle algorithm to traverse it
• Examination of results
  – With a metric to test straightness
• Exploration of proposed method’s potential
What’s Been Done?

- Compound motion on regular grid defines direction
  - Change of angle isn’t smooth
  - No curvature
    - Tim Tyler, finitenature.com

- Probability as direction
  - Replaces continuous motion with continuous probability
  - Preconceived orientation required
Our Discrete Medium

• **Irregular Directed Graphs**
  - No preferred directions
  - Minimal data at each node
  - Directed links add room for subtlety later

• **Graph Recipe:**
  - Give many nodes random coordinates in a fixed area
  - Connect each node to all others within threshold distance $d$
  - Hide coordinates
What is Straight?

- Shortest distance between two points...
  - Via which route?
  - Which result?

Could be in a space with any dimensionality
The Jellyfish Algorithm

- Two sets of nodes, size n: A & B
- For every neighbor of $A \cup B$, allocate a score
  - Add one for each adjacent element of A
  - Subtract one for each adjacent element of B
- New B = A
  New A = top scoring n neighbors

For each neighbor node x, score is: $|A \cap \text{neighbors}(x)| - |B \cap \text{neighbors}(x)|$
Jellyfish in Action

100K graph nodes not shown, 50 nodes in A, 50 in B

**Straightness dependent on graph conditions!**
Quantifying Straightness

- Want a metric that ignores changes over short distances
  - Angles at short distances are guaranteed!

- Measure direction change over time
  - Compare $P_{t/2} - P_0$ with $P_t - P_{t/2}$
  - We know the real angles!

- Average over many runs
Angular deviation for different set sizes with varying connection density
Angular deviation with connection density for varying particle size.

Angular deviation for different connection densities with varying particle size.
Angular deviation for set size (mean neighbors)/2 with varying connection density.
Did Irregular Graphs Help?

Yes!

Regular graphs bend the direction of flight for every algorithm tested
Adding Dimensions

Not a problem
Variable Curvature: A Potential

- Try for a force that goes as $1/r^2$
- Build graph by linking based on probability $P_L$ as well as radius threshold
- For any two nodes, $P_L$ depends on relative distance from G
- Links more likely to be added that point toward G

$$P_L = 0.5 - \frac{GB-GA}{2t(1 + GA + d)^2}$$

$t = \text{threshold dist.}$ $d = \text{damping func.}$
Jellyfish in Orbit

Slightly exotic orbits chosen on purpose!
How Far Can We Stretch?

- Exploring the Potential of Jellyfish:
  - Special Relativity
  - Quantum-Wave Behavior
Special Relativity - Part One

- Let’s borrow a trick from Kaluza-Klein Theory
- \( s^2 = t^2 - x^2 - y^2 - z^2 \), so add an axis for \( s \)

- KK Theory is defunct, but we’re just exploring 🙄
Without interaction, demonstration is incomplete
However, particles conform to Lorentz metric
Quantum Behavior - Part One

Look what happens when we start Jellyfish
Quantum Behavior - Part Two

Look what happens when Jellyfish divides

Using coarse graph here to highlight effect
What Can’t Jellyfish Do?

- No self-interference
- No wavelength
- Background dependent
  - Worse: dependent on canned dimensions
- Monolithic Algorithm
  - Unlike CAs
- No motion across trivalent graphs
Conclusions

• Irregular graphs worked well
  – Denser graphs improved performance

• We approximated straight-line motion
  – Though never perfectly

• We don’t have a digital photon yet
  – But we do have a test particle

• Reach of digital physics extended
  – Very well placed to explore further
Next Steps

• **Background Independence**
  - Nodes in spacetime
  - Graph deformation by particle
  - Jellyfish as nodes

• **Algorithm extension**
  - Interaction
  - QM behavior: polarization, spin, all paths, etc
  - Improved relativity

• **Generalizing and searching the rule-space**
  - Break Jellyfish into simple operations on node sets
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Video Samples

**Motion in 2D**
http://www.youtube.com/watch?v=Y_yCxcjYPmo

**Motion in 3D**
http://www.youtube.com/watch?v=3w4A6m26WI4

**Deflection by regular graphs**
http://www.youtube.com/watch?v=Me6K4weLS5c

**Geodesic motion**
http://www.youtube.com/watch?v=n3jnKejhX-Q

**Relativistic motion**
http://www.youtube.com/watch?v=ggd8Z1fZwTA

**Quantum-like collapse**
http://www.youtube.com/watch?v=qUrqKhBwjGw