

# Congestion - Mimesis of traffic flow

Peter Todd

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## **Abstract**

Taking heed of the approach of physics towards examining reality, constructing laws, and deducing consequences, here we explore the process of creating an algorithmic work of art, through an iterative approach based on the steps of examining the underlying logic of traffic and traffic networks, constructing rules inspired by this logic, and examining the consequences of those rules. However, where in physics the goal is one of prediction and explanation, here we strive to create rules that are an impression of reality.

## **1 Background**

### **1.1 Discovering equations**

Physics is the application of math to predict and explain reality. In practice, the advancement of physics is a process in which two main actions occur: experimentation, and theorization. Experimentation, done by experimentalists, usually consists of a controlled situation in which the experimentalist sets up a scenario in reality, and then collects data as they observe the result. In contrast a theorist considers what is already known about physics, and tries to imagine further rules that could describe reality better.

Now suppose an experimentalist decides to collect data on what happens when objects are dropped. After dropping a large number of objects and recording the details of each fall, he will notice first that the objects always seem to move towards the ground. He will then notice that the time taken for the

object to fall a given distance appears to be related to the distance,  $t = kd$ , where  $k$  is a as yet unknown constant. Playing with the numbers further he notices that the relationship between time and distance is not linear; the amount of time taken does not increase proportionally and indeed it decreases as  $d$  grows larger.  $t = k\sqrt{d}$  fits, although the constant is still required. The experimentalist publishes a paper at this point, “On the behavior of various kinds of falling fruit”, (title translated from the original Latin) and comes up with tables showing  $k$  for apples, oranges etc.

Our theoretician hears of this work and begins to think. The table of constants in the experimentalists paper are to him, ugly; they represent hacks that make an equation fit results, without any understanding of the underlying process that is at work. He is also aware of other published works attempting to describe how much an object pushes downwards when at rest, and other such experiments being done by his contemporaries. He starts to think that perhaps the heaviness, the downward push, objects have at rest is somehow related to how they fall. In a related phenomenon, it is known that if one pushes an object along a floor, it will move. Crucially, the sensation of pushing an object in this manner feels no different to the push that the object creates when it is held. The theoretician then decides to give this pushing-sensation a name: force. He notes that objects seem to have an intrinsic force downwards, which he calls mass, from massiveness, giving the relationship  $F = m$ . This fits with a paper on balanced weighing scales that a contemporary has produced, which noted that not only could a weight put a balance beam into equilibrium, but that a pushing force, for example one exerted by the experimentalist’s arm, could also balance such an object. Since a force can also cause an object to move, such as the case of a ball being thrown, an objects intrinsic force downwards should also cause it to move, towards the ground. To shorten our story, lets assume he has a concept of friction, and is already considering idealized thought experiments without it, leading to the concept that displacement is a function of velocity and time,  $\Delta d = v\Delta t$ . Since we are, at this point, already considering that velocity is fixed, we have Newton’s first law. As stated by Newton himself:

Every body persists in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed.

The next leap is to consider how such a force changes the objects state. The theorist already thinks

that the downward force due to an objects mass is constant, and for an object at rest, it is only an upward force applied by the surface on which the object rests that balances out the downward force. Lets assume he is also referring to the change in velocity over time as acceleration. He could say that the downward force accelerates the object, because obviously its velocity continues to grow during its fall. If that growth is fixed, then  $v = kt$ , with  $k$  being some sort of constant factor. Drawn on a graph, such a relationship would yield a triangle, with the height of the triangle representing the velocity at the end of the time period. Now, mathematicians studying geometry already know how to calculate the area of a triangle, so using that we can determine how far the object will fall, in a given amount of time,  $d = \frac{1}{2}kt^2$  and solving that for  $t$  gives us,  $t = \sqrt{\frac{2d}{k}}$

“Ah-ha!” says our theoretician, “That equation looks just like what my colleague studying falling fruit came up with!” Now he has just one more question: what is this  $k$  constant anyway? Jumping ahead again, lets say he has realized that acceleration is proportional to the force, divided by the mass of the object,  $a = \frac{F}{m}$  He also knows that the downward force, which he is now calling gravity, is proportional to the mass of the object  $F_g = mg$ , where  $g$  is the acceleration due to gravity. Substituting that into his acceleration equation gives  $a = \frac{mg}{m}$ , the mass terms cancel out, meaning that an object, no matter what its mass is, will accelerate towards the ground at the same rate,  $a = g$  Of course, actual observations don’t show this to be true, objects like a feather fall far slower than a cannon ball, but at this point our theoretician has come up with the idea of friction due to moving through air, drag, and may even understand its exponential growth as  $v$  grows,  $F_d = kv^2$ , causing the two forces to balance at some given velocity, the terminal velocity, where  $kv^2 = mg$

All of the above chain of logic is fairly easy to check against reality with tools available to Newton, and in reality Newton acted both as an experimentalist, and as a theoretician, although the exact line of logic presented above (and continued below) is purely the authors imagination. In any case we are still left with determining just what is  $g$ ? Suppose that all objects with mass attract *each other*? We could say that  $Fg = km_a m_b$ , although it seems that more likely would be that the distance between the objects comes into play somehow,  $Fg = k\frac{m_a m_b}{d}$ , otherwise one would be as equally tugged by a rock very far away, as a rock nearby.<sup>1</sup> To make a long story short, we’re nearly at Newton’s law of Universal

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<sup>1</sup>Indeed, many consider that exact sort of infinite reach of effects to be exactly why software, which runs on Von

Gravitation,  $Fg = G\frac{m_a m_b}{r^2}$ , although it turns out that the force drops off by the square of the distance. This equation *is* consistent with our previous force due to gravity equation, although only if  $m_a$  is very large compared to  $m_b$ . It also tells us that  $G$ , our “gravitational constant” must be a very small number, as the Earth is very large, which would also explain why no one has been able to observe this force between two objects.<sup>2</sup> Remember though, we can’t test this theory, at least not with the tools available to us. What we have come up with is in fact, theoretical physics.

## 1.2 The elegance of equations

Physicist Murray Gell-Mann states that in fundamental physics there is an idea that “a beautiful or elegant theory is more likely to be right than a theory that is inelegant” [16] It is indeed surprising just how far this concept can be taken. Gell-Mann relates how Einstein frequently brushed off criticism of his work, even from scientists who had performed experiments that seemed to contradict his theories, on the basis that the equations of his theory were far simpler than the more complex equations of his detractors. Ultimately, Einstein was right, and the experiments flawed.

Between “objects fall” and Newton’s Law of Universal Gravitation, we’ve shown a thought process that goes between basic observation, to what at the time was theoretical physics. Of course, theoretical physics often doesn’t stay theoretical for long, and universal gravitation soon turned out to describe the motions of the planets quite accurately. What we haven’t yet shown, is similarities between equations for seemingly unrelated phenomenon. For instance the force between two charged particles is described by Coulomb’s Law,  $F = k_e \frac{q_1 q_2}{r^2}$ , which is identical to the law of universal gravitation. Similarly Einstein’s famous  $E = mc^2$  is identical in structure to whole hosts of other relations, like the above mentioned  $d = \frac{1}{2}kt^2$ , which in turn is identical<sup>3</sup> to the energy of a moving object,  $E_k = \frac{1}{2}mv^2$

Gell-Mann explains these strange similarities by describing physics first as the description of a logical system, and proceeding from there, as an onion skin, with each layer resembling the previous one to some

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Neumann machines, is so unreliable: one can’t simplify the reasoning of interactions, if everything interacts equally with each other.

<sup>2</sup>As it turns out the value of  $G$  is  $6.673 \times 10^{-11} Nm^2 kg^{-2}$ , a value so tiny it was only until 1798 that it was measured by Henry Cavendish, 111 years after Newton hypothesized the inverse-square law of universal gravitation in Principia.

<sup>3</sup>Don’t be fooled by the  $\frac{1}{2}$ ; the *structure* is equivalent as we could have simply defined mass to be half of what we happen to define it as, and simply add a 2 to any  $m$  in other equations.

extent. He states:

The result is that newly encountered phenomena are described rather simply, and therefore elegantly, in terms of mathematics close to what was already developed for phenomena studied earlier. That is a property of the basic law, not of human observers. The manifestations of the law at different scales exhibit approximate self-similarity. Newton called it “Nature Conformable to Herself.”

While the exact reason why this should be so is a matter of debate, it is in part due to the nature of mathematics itself. Mathematics studies self-consistent logical systems, shifting between the discovery of new systems, and the design of new systems. The balance between these two paradigms is fuzzy, and ultimately a matter of taste. These systems, whether discovered or designed, are then harnessed by physicists who use them to study reality. The crucial point is that the logical systems which best describe reality are usually simple, and due to the scarcity of simple systems, the same lucky few appear again and again.

Of course, that is not to say that the *results* of applying simple logical systems are themselves simple. This is to be expected; we know nature to be astoundingly complex, therefore the output of an equation that purports to describe it should be as rich as nature itself. Take for example the well known Mandelbrot fractal. It is defined as the set of complex values of  $c$  for which the orbit of 0 under iteration of the complex quadratic polynomial  $z_{n+1} = z_n^2 + c$  remains bounded; Chaos Theory shows that iterating seemingly simple rules can produce results of infinite depth and complexity.

## 2 Application

When you go out to paint, try to forget what object you have before you - a tree, a house, a field, or whatever. Merely think, here is a little square of blue, here an oblong of pink, here a streak of yellow, and paint it just as it looks to you, the exact color and shape, until it gives you your own naive impression of the scene before you. - Claude Monet

## 2.1 Impressions of reality

Visual art is often some kind of representation of something in reality. The degree, and kind of representation is of course up to the artist. Whereas a painter following the realism style would try to carefully follow the rules of perspective to generate an “objective” image as would be seen in reality, at the other end of the spectrum Mondrian “not only reduces art to its essential parts; in *Broadway Boogie Woogie*, he distills an image of New York City.”[27] While the physicist is always constrained by the eventual end goal of describing reality accurately, when we as artists try to construct systems of rules we have more freedom. Of course the rules we create may lift themselves entirely out of the realm of reality, such as the underlying logic of John F. Simon’s work, “Every Icon” which simply enumerates every possible combination of black and white pixels in a  $32 \times 32$  grid. This rather large number,  $2^{1024}$ , is a mathematical game; using the Bremermann’s Limit of  $2.56 \times 10^{47}$  bits/kg[6] and the universes mass of  $3 \times 10^{52} kg$ [10] we find that were the entire universe turned into energy and unleashed in one giant orgy of computation we would have flipped  $7.68 \times 10^{99}$  bits, still well under the required count<sup>4</sup> of at least  $1.8 \times 10^{308}$ .

Monet’s approach of “naive impression”, applied to the rules of reality, can be seen in video game design. If a designer seeks to create a fun and engaging experience for the user, and seeks to allow the user to create some form of “virtual physical” body image, the rules of the game world must at some level emulate physical reality.[17] However there is no need to slavishly emulate reality, and often the most fun games are those that specifically choose to make use of artistic license in their interpretation. In *Super Mario Brothers* both friction and momentum are emulated: “If Mario is running quickly before he jumps, he travels farther than if he was walking before the jump. And he slowly slides to a halt depending on how fast he was running. Using software to emulate real world physics made the game more intuitive.”[19] However, when falling the player can control Mario’s descent to a degree, moving the virtual character slightly to the left or right, when in reality without some form of thruster or sail such action is effectively impossible. This departure serves to maintain the players sense of control and their interaction with the game, even if not physically correct. Of course, neither are mushrooms that

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<sup>4</sup>In fact, larger, the number of bits flipped per increment is only a minimum of one, and a maximum of 1024.

make one grow larger.

While Monet painted as the eye sees, or perhaps, should see, the designers of Mario saw the rules of reality as a human sees them, or would like to see, creating rules that allow for interaction when strictly speaking there is none.

## 2.2 Random walks

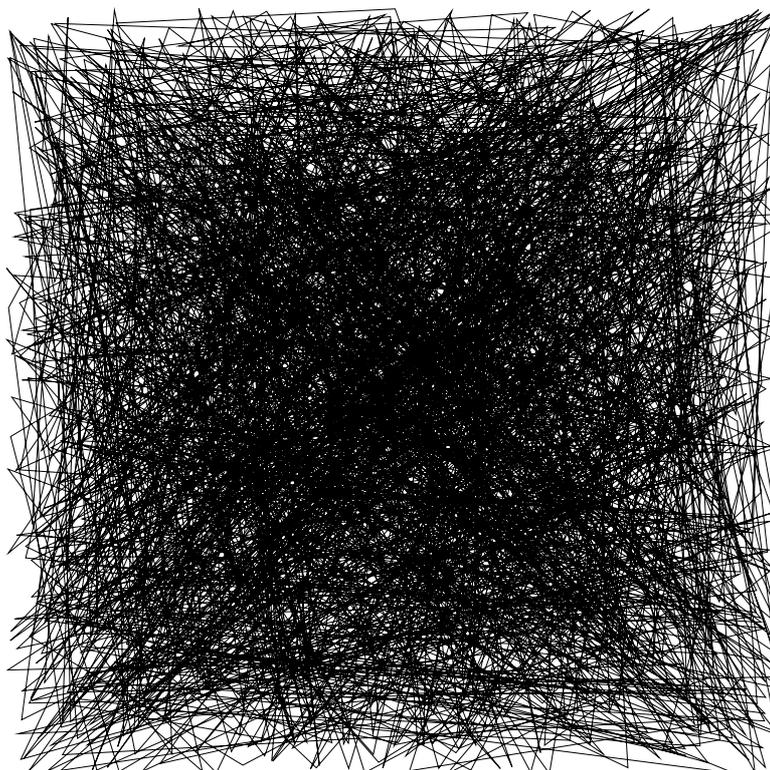


Figure 1: Scatter

Suppose we have a two-dimensional plane, and on that plane an ant is placed. This ant carries a roll of string, and the end of the string is fixed to the ant's initial position. Now we have the ant jump to a random location on the plane 5000 times. Given a sequence of random locations,  $Z_{1...n}$ , we could say that the ant's location,  $S$  at step  $n$  is  $S_n = Z_n$ . Figure 1 is the result of this experiment. Notice how the image is distinctly denser in the middle. This is due to the fact that it is more probable for a randomly

placed line to intercept the middle of the plane than the edges. Analogously a pile of sticks dropped in an area would produce the same effect.

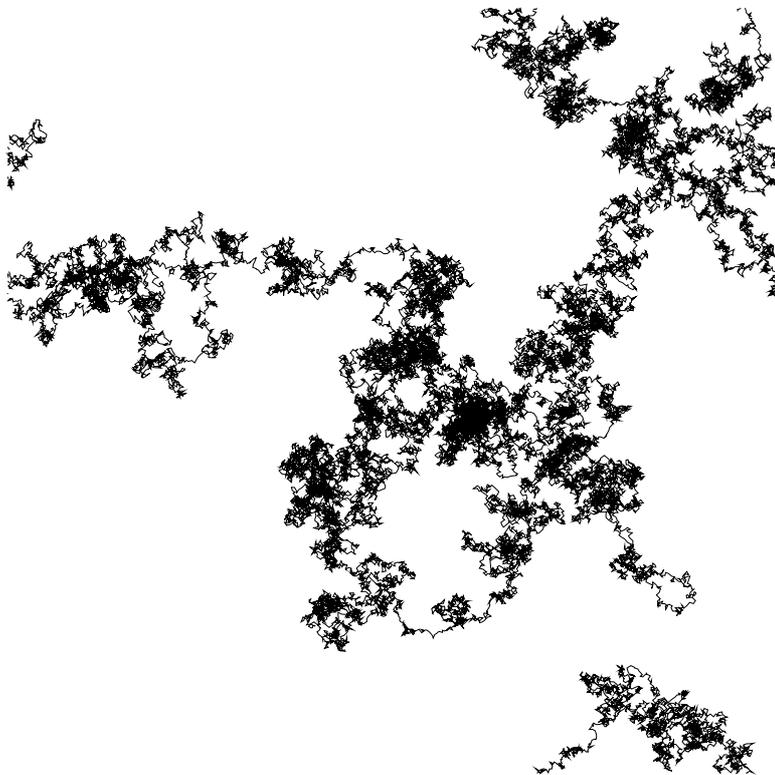


Figure 2: Random direction

Now instead of jumping to any location on the plane, we tell our ant to only move up to a given amount, in any direction. We will also tell it that should it wander off the edge of the map, to simply reappear on the other side. For a single Cartesian axis, and using modular arithmetic, we can now say the ants position at step  $n$  will be  $S_n = \sum_{j=1}^n Z_j$  where  $Z_{1...n}$  are independent random variables in the range  $-k...+k$ . Given a small enough  $k$ , the result looks like figure 2. This is known to math as a random walk.

Finally lets add a notion of momentum to our ant. Now it will remember which direction it was walking in, and we will ask it not to pick a new direction at each step, but rather to shift its direction slightly, either to the left or to the right. We will skip the math this time, which now is usually represented

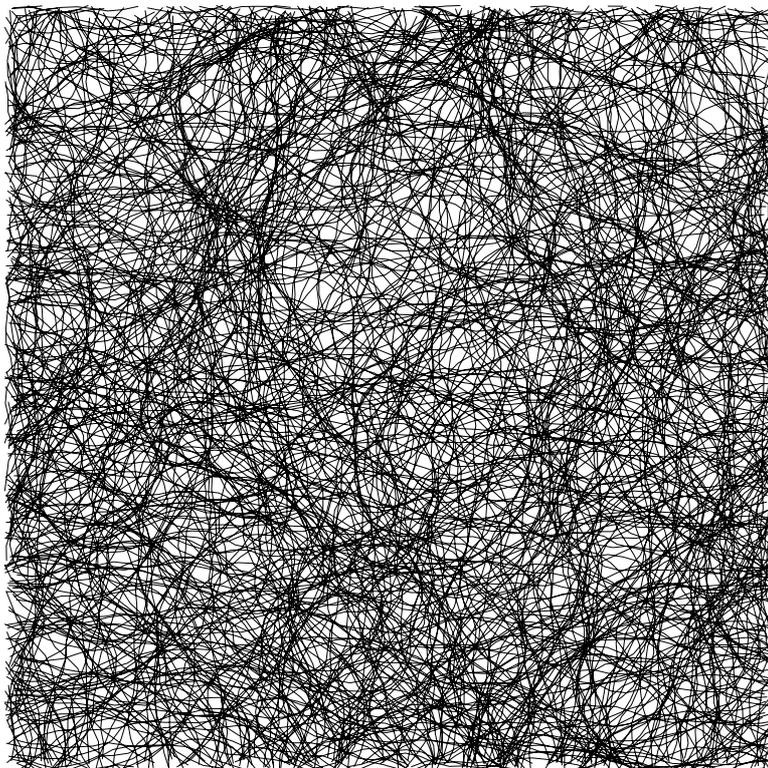


Figure 3: Wandering angle

with phasors, as we are beyond the limits of high-school notation, but the result can be seen in figure 3. This time our result looks rather like a microscope image of matted felt. The reason is simple: felt is made up of randomly arranged fibers pressed together, each fiber has a certain characteristic amount of give to it, and therefore will form gentle curves. We now have a rule that gives roughly the same results as a totally different system, or alternately can be seen as an approximation of a system.

### 2.3 Demographic density

Figure 4 is derived from the well known “Earth at Night” photo published by NASA.[21] In it we see the amount of light emitted at night by the eastern side of the United States, as well as eastern Canada, which in practice acts as measurement of population density. We can see that the distribution of density is not evenly distributed, while there are a great number of small cities, there are only a few large



Figure 4: Light pollution at night

cities. In essence people appear to clump together. It has been shown that this distribution of city size and probability matches what is known as a power law distribution, which is a type of distribution very commonly seen in nature; the common rule of thumb “80% of a is the result of 20% of b” is a consequence of this common distribution.[11] Suppose we decide to model the number of cities, and their populations, as a power law of the form  $P_n = Cn^{-k}$  where  $n$  is the population and  $P_n$  is the probability of a city with that population. Already we can see a problem in our model: very small cities seem unreasonably unlikely, the peak of the probability curve is at 0 population whereas we can think of little reason to live in such a small “city”. It is also difficult to think of how to turn that distribution, back into a map for our purpose of creating visual art.

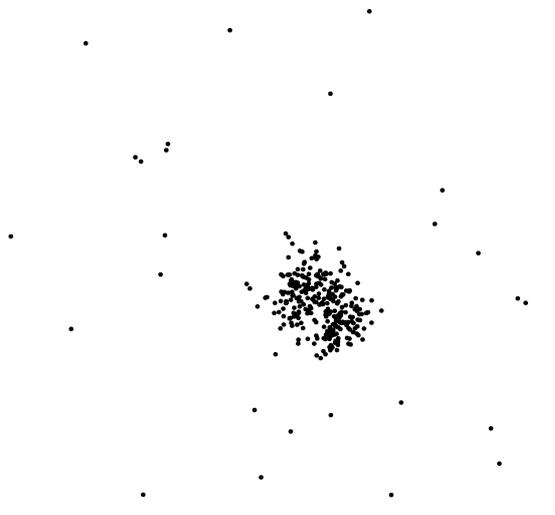


Figure 5: Demographic gravitation,  $n = 300 g^2 r^3$

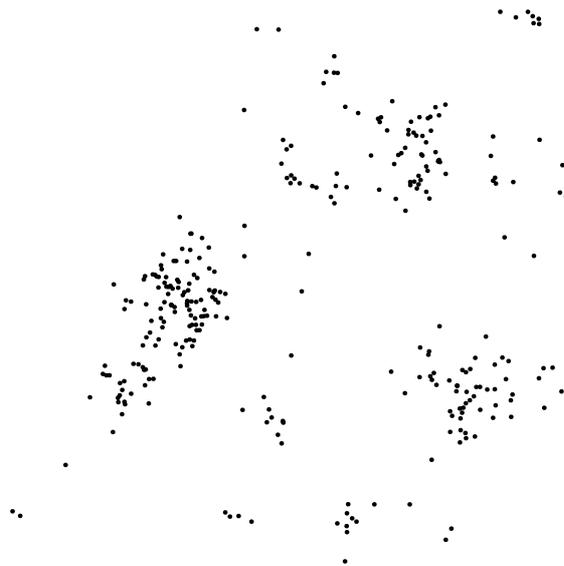


Figure 6: Demographic gravitation,  $n = 300 g^3 r^4$

John Quincy Stewart's concept of demographic gravitation gives us another alternative. By applying Newtonian formulae of gravitation to that of "the average interrelations of people" on a wide geographic

scale, he treated sociological interactions as microscopic applications of a formula, creating macroscopic effects:

Fortunately for physics, the macroscopic approach was the common-sense one, and the early investigators - Boyle, Charles, Gay-Lussac - were able to establish the laws of gases. The situation with respect to “social physics” is reversed... If Robert Boyle had taken the attitude of many social scientists, he would not have been willing to measure the pressure and volume of a sample of air until an encyclopedic history of its molecules had been compiled. Boyle did not even know that air contained argon and helium but he found a very important law.[28]

Suppose that we were to model a population of individuals on a plane. Like Stewart, we assume that each individual is attracted to one another according to  $F_g = G \frac{m_a m_b}{r^2}$ . This rule alone would of course simply cause all the individuals to collapse into a single point, similar to the formation of a black hole. Therefore we need to add another term, repulsion, with  $F_r = -R \frac{m_a m_b}{r^3}$ . Note how our repulsive force goes up not by a square, but rather by a cube. This is important, as we have to make a transition between the dominance of attraction, and the dominance of repulsion. Between these two forces we can say that the total vector force on any individual  $i$  is the sum of the forces of attraction and repulsion from all other individuals,  $\vec{F}_i = \sum_{j=1}^n (G \frac{m_i m_j}{r^2} - R \frac{m_i m_j}{r^3}) \vec{u}_{ij}$  where  $\vec{u}_{ij}$  is the unit vector from  $i$  to  $j$ . To actually use this system we write a small program to simulate the moment of the individuals subject to these forces using discrete time steps, better known as numerical integration. At this point each individual simulated has a mass  $m$ , a position  $\vec{p}$ , and a velocity vector  $\vec{v}$ . To keep the time steps manageable the velocity is limited by adding a drag term, proportional to the square of the velocity,  $\vec{F}_d = -k\vec{v}^2$ . Of course, any such system, iterated long enough, will converge to a single large ball of individuals, so we arrange for one in ten “individuals”, to have their positions fixed, representing resources, and set their masses to be 10. The results of this system converge to what is shown in figure 5.

Interestingly essentially all combinations of the  $G$  and  $R$  constants lead to this result, with the central ball on getting more or less dense depending on the ratio of gravitation to repulsion. Changing the exponent of the gravitation equation to  $r^3$  and the repulsion equation to  $r^4$  however yields the far more interesting results shown in figure 6. While certainly not the eastern seaboard, we are beginning

to replicate the macro-structure of it.

This discrepancy in exponents may be due to Stewarts inability to run this kind of simulation at the time he published “Demographic Gravitation: Evidence and Applications” in 1948. Although he was able to calculate by hand contours of “equipotent demographic gravitation”, trying to imagine movement due to gravitation, as the above model does, creates a system equivalent to the well known N-body problem which can not be solved except by laboriously calculating steps. Even with just 300 objects, that leaves 90,000 relations to be calculated at each step; annoyingly slow even for the author’s 2010-era computer.

## 2.4 Traffic and paths

Our model of population density needs paths. The path itself is simply a way of satisfying the criteria of completing a trip between two points, which is turn is driven by some sort of need to visit the second point. Unfortunately the nature of “need” is inherently extremely complex, so in the spirit of mimesis, as opposed to modeling, we will use the most simple possible model. Interestingly traffic simulation as an engineering discipline generally approaches this problem similarly, relying mainly on measurements of existing traffic streams,[3, p.2-1] and assuming that the proposed changes to the traffic network being studied will not change trip choice.

Figure 7 was produced by repeatedly picking trip source/destination pairs at random and simulating the trip. Both source and destination were picked from all possibilities with equal likelihood. The trip was plotted by simply picking the closest node that would be closer in a straight line to the destination. While this very simple heuristic does result in having multiple paths plotted for some long distance jumps, one could argue given a generally dense network it is probably adequate. It’s also similar to the way the well known A\* path-finding algorithm finds initial best guesses. The graphic shown makes the path line width linearly proportional to the number of trips taken, and well used corridors are easily seen.

Figure 8 shows the result of the above model changed to artificially reduce the “distance” between nodes by one half each time a path is traversed. This simple change eliminates most of the extra paths generated by the previous model. The road generation was also changed to use something akin to the

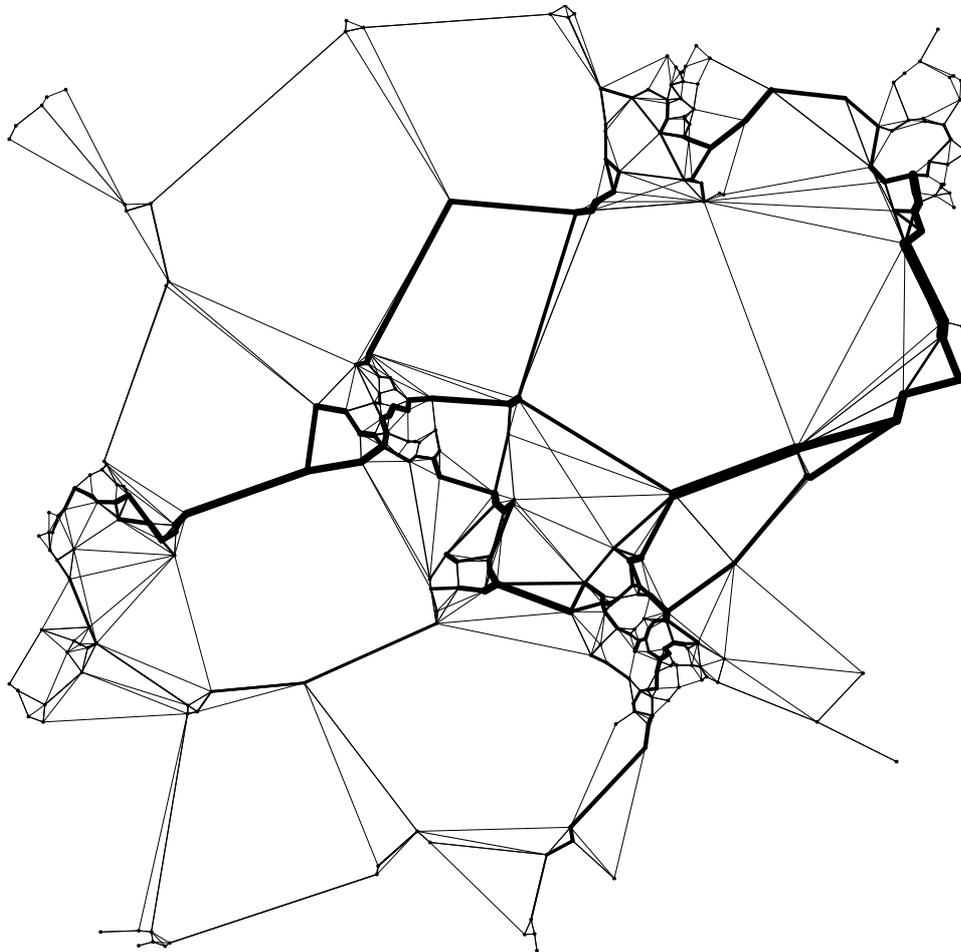


Figure 7: Path generation,  $n = 300$

wandering angle random walk in figure 3 to add micro-scale randomness. At this point the final result is visually very akin to a organically grown road network, without having to use any type of external data source. As an experiment this second model was also modified to only select destinations from one in every ten possible destinations, interestingly, no visible change was seen in the result, likely due to the “artery” paths already carrying traffic for more than one destination.

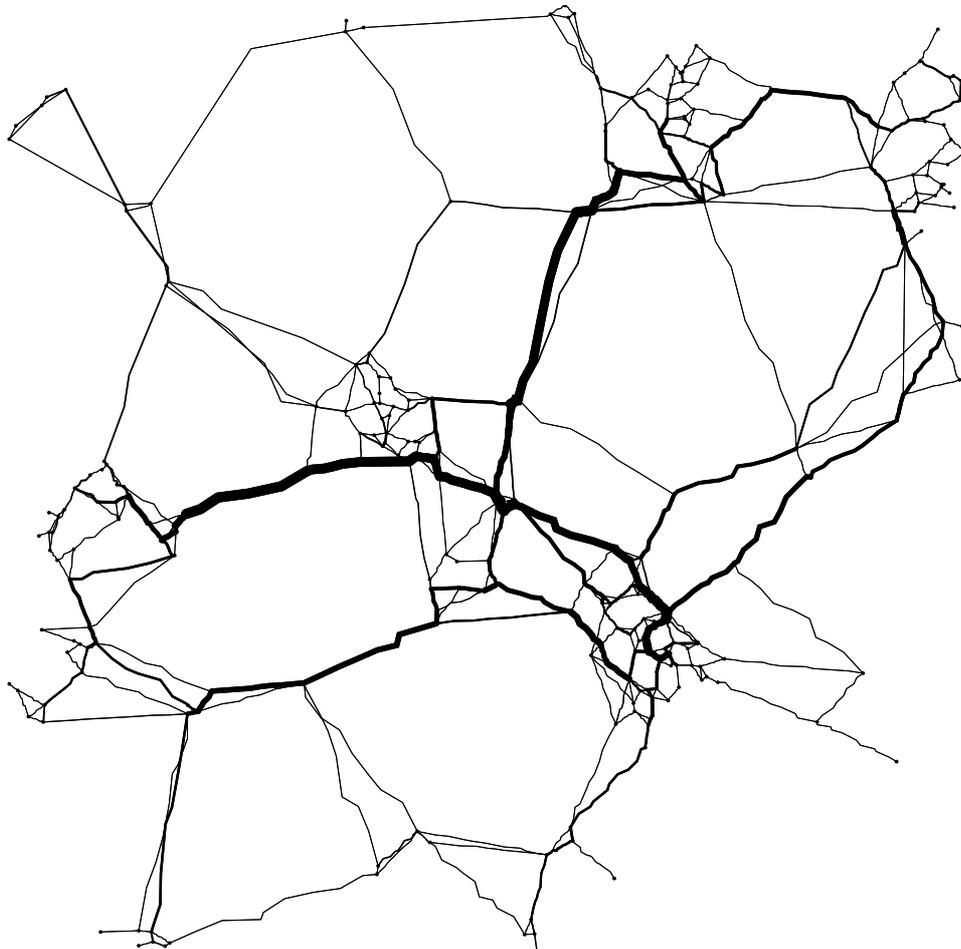


Figure 8: Path generation, dynamic distances,  $n = 300$

## 2.5 Traffic dynamics

At this point a workable simulation is close to complete. A network of paths, and a usable trip generation model is in place, leaving only the actual simulation of traffic at the micro level. A detailed discussion of the models used for this task is probably better left to a medium allowing the viewing of the algorithm results, such as a talk or video, so it will suffice to say that the literature of traffic simulation calls this kind of simulation a microscopic flow model,[3, p.10-6] where individual cars are simulated according their capabilities of acceleration and deceleration, and the human factors of acquisition of information, and

response to that information.[3, p.3-3] The result is known as a car-following model, creating an equation describing the final stimulus-response mechanism, a relation similar  $a_f = F(v_l, f_f, s, d_l, d_f, R_f, P_i)$ , where  $a_f$  is the resulting acceleration.[3, p.10-9]

## 2.6 Presentation

All of the models presented so far have implicitly assumed a network on a two dimensional Cartesian plane, which is an obvious approximation of most real life traffic networks. From the perspective of information transfer to the viewer, the optimal viewpoint for such a set of data is obviously perpendicular to the plane, the top-down view, allowing simultaneous visibility of all data present. It is no surprise that this view, or occasionally the slightly modified isometric view, is used by practically all traffic simulations encountered. Indeed this notion of the informational content of the top-down view is touched upon by artist John Vander Woude's "Airports" series of satellite imagery of airports: "These easily found and printed satellite images of the supposed 'battlegrounds' of terrorism shows the tension between freedom of accessibility [of information] and the power of having that accessibility." [31] Even inherently one dimensional information is generally represented in a two dimensional form: this thesis paper, which is generally consumed as a linear sequence of alphabetical characters, is formed first into two dimensional paragraphs and then into pages for viewing.

The second inherent assumption has been the rejection of representation. Where the mathematical model so far developed takes reality, and creates an abstracted model of it, the choice of a simple black and white representation takes the data produced, and as far as possible imposes no further representation on it. It is interesting that this approach seems to be never followed in simulations attempting to simulate specific realities; the verisimilitude of the graphical output to reality only increasing over time as resources are available to improve it. Similarly the underlying models of such simulations will reference real world units, such as kilograms and meters, where the underlying code used to generate the above figures has all used unitless representations; a position is not a given number of meters to the east and meters to the north of the origin, rather the visible plane is the rectangle (0,0) to (1,1) and a point in the center is simply at (0.5,0.5)

### 3 Optimizing audience, aesthetics and impact

”There’s over 40 walls in the average American home,” a business manager for the artist Thomas Kinkade once said, ”and Thomas says our job is to figure out how to populate every single wall in every single home and every single business throughout the world with his paintings.” [7]

Implicitly every step in creating Congestion has been made in reference to some sort of value metric. Choosing to go down one path of implementation or another requires some way of evaluating the choice to optimize the result, but what is that metric? In computer science the study of genetic algorithms, where a solution to a problem is found by creating multiple candidate solutions using a genetic representation, and then breeding the solutions evolutionarily over multiple generations, has been mainly stymied by the difficulty of coming up with suitable fitness functions to evaluate the solutions created.[30, p.95] Viewing the creation of art as a kind of memetic evolution,[15, p.368] sampling memes and recombining those memes into new memes, along with also creating entirely new ones, we see that while judging fitness after the fact is easy, publish and show the art work and see if its memes reproduce, predicting the results of the act of publishing before doing so requires some sort of fitness function.

#### 3.1 Audience

At one extreme the work of commercial artists such as Thomas Kinkade is illustrative. He states that his art is meant to have broad appeal:

There’s been million-seller books and million-seller CDs. But there hasn’t been, until now, million-seller art. We have found a way to bring to millions of people, an art that they can understand.[23]

His “way” appears to be paintings rendered in an impressionist style of subjects such as idyllic gardens, cottages, as well as patriotic and religious themes such as soldiers returning home and churches. He has even painted, in a serious fashion, the Indianapolis 500.[2] The appeal to his audience appears to

be a combination of familiar themes, rendered in ways that are both aesthetically pleasing when evaluated by common standards, and familiar as well.

At the other extreme of audience is artists such as Joseph Beuys, whose 1965 performance “How to Explain Pictures to a Dead Hare”, “an examination in complex tableau form of the problems of thought and communication with reference also to ritual, magic and myth” [13, p.872] was first experienced by the author as a second year fine arts student taking a class in the history of 20th century art. This experience is probably common, and suggests that Beuys is an artist with an audience of primarily artists and other cultural workers, who experience the artwork through discourse about the art itself, as opposed to the Kinkade model of experiencing the art directly.<sup>5</sup>

To optimize the experience of the audience for the Congestion artwork it must be considered who that audience, or sub-audiences are, and how to interact with the artwork. The viewer seeing the artwork in a gallery setting will likely only experience the visual aspect of the work, and at best read a short artists statement. For that audience attention must be paid to the need to “grab” attention and provide something visually interesting to look at. This audience may have a very limited understanding of what is going on; in the authors experience similar works of art are often not even recognized as simulations, but rather assumed to be videos.<sup>6</sup> For that audience aesthetics and the perception of underlying logic are important, the former hopefully achieved by appealing to the commonly seen tastes in minimalist design, the latter by considering something akin to the appeal of watching an ant nest with a magnifying glass.

The second main audience, who’s interaction with the artwork includes interaction with substantive discourse, such as this thesis paper, includes teachers, fellow students, friends, family and the author’s technically and scientifically inclined coworkers. In optimizing their interaction, especially with the audience of coworkers and similar, the approach of Randall Munroe, creator of the webcomic xkcd, who has made available webgroups where fans obsessively discuss the themes of each weeks comic, is appropriate:

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<sup>5</sup>Although, Kinkade *does* have a secondary audience of cultural workers experiencing his work indirectly through discourse, and has been described as a post-modern artist in the tradition of “anything goes”. [25]

You are part of that audience.

<sup>6</sup>Granted, from an information theoretic viewpoint, it is hard to say that they aren’t: with no dependency on outside stimulus the computer program underlying the visual can be seen as simply a highly effective data compression codec, similar to how rather than recording  $n$  digits of  $\pi$ , one can simply write “The first  $n$  base-ten digits of the ratio of a circle’s area to the square of its radius.”

Be clever.

## 3.2 Aesthetics

Here we use the term aesthetics to encompass not only the visual content of the work, which could be simply analyzed via graphics design and in theory ultimately by the science of human vision, but rather the immediate impact of the work, the zeitgeist of the viewer's short term experience when viewing the work. This can be compared in a fashion to the experience of someone upon listening to a work of music, the complex set of logical and emotional responses. Classical and electronic music, specifically IDM, both make good models here, and considering how the latter leverages technology, we will use it as our example.

Intelligent Dance Music, IDM, is an appropriate analogy. As a genre "the label 'IDM' seems to be based more on an association with individualistic experimentation than on a particular set of musical characteristics.",[9, p.80] yet the music produced is highly recognizable, not directly as a specific sound, but as a way of composing music, that implies a way the listener listens to it. Ralf von Appen argues that "Music has a purely sensual attraction so that we forget all considerations of purpose for a short while in order to just listen and yield to the music and its own laws. Those who are not musicologists nor play an instrument have a certain advantage here, like a listener to lyrics in languages that are not his own." [29] This suggests a notion of discovery, in that a lack of understanding allows a more immersive experience. To that aim the notion of a genre focused on exploration seems to meet this approach to aesthetics.

The composer David Cope takes this exploration a step further. In his book *Computer Models of Musical Creativity*[12], he explores models by which computer programs can model creativity itself, and he has also used these models to compose a significant body of work. The reaction to his work has been mixed, and often very negative, but it does appear to be able to perform feats such as producing multitudes of Bach-style chorales.[5] The algorithms themselves use recombination and pattern matching, and analyze allusion to prior musical ideas to generate their output. He states that "newness is often merely an enlightenment of older, but possibly lesser-known, ideas"[12, p.xi] suggesting that both the

new and familiar contribute to the enjoyment of the output. The way that Congestion tries to create models from existing visual systems can be argued to be analogous to this process, although executed by human creativity as opposed to algorithmic. This does raise the question of the rate of new ideas, comparing different genres of music one could say that the rate of new ideas varies between the more popular, and more experimental, just as the rate of new ideas in a Kinkade is less than in a Beuys, although neither case really sheds much insight into aesthetics, and it may be that the processes by which music alludes to prior ideas, being sound and language, do not translate into the visual.

### 3.3 Impact

Going back to the concept of memetic evolution gives us a way to measure impact. If a work of art presents and promotes a certain set of given ideas, we can try to optimize the degree to which those ideas are passed on to further works, and we can think of that degree as the impact of that work. Measuring the number, and significance, of the references to an idea is well known concept. This is essentially what the Google Page Rank algorithm does, if one defines ideas as webpages and references as links. Similarly citation analysis is increasingly used in the academic community to gauge the importance of papers.[22] Using this concept we can say, in a somewhat value neutral way, that an artist such as Kinkade is less valuable than Beuys, by arguing that the concepts in Kinkade's work are not further developed on and referenced anywhere near as much as that of Beuys, even if the former appears to have a far greater number of viewers than the latter. Similarly Munroe seems to be highly influential in his ability to distribute ideas. Take for example his comic "Map of the Internet"[24], which referenced the mathematical concept of a hilbert curve, and created what was apparently the new idea of representing a computer address space, in this case the set of IPv4 internet addresses, as a hilbert curve fractal, to better show which internet addresses were closer to one another. This idea then transferred to the realm of computer science, when researchers at the University of Southern California, Information Sciences Institute, rendered their latest census of the internet address space as a hilbert curve.[1]

The transmission characteristics is a meme in the realm of art, and the realm of science and math, are arguably very different, simply because the latter has more clear ways of deciding value. In physics an idea

can be evaluated on its ability to predict reality, which given good data can be a fairly simple and value neutral process. In math an idea can be evaluated to determine if it is consistent with other systems already accepted, and upon successful completion of a proof, this consistency can be assured making the idea in fact, true. What ideas are more valuable than others is generally agreed upon, although "Usefulness is one main criterion, but often it is usefulness in creating more mathematics rather than in the applications to the real world"[18]

Compare that to the memes surrounding Jennifer Baichwal's influential documentary, *Manufactured Landscapes*. [8] In it Baichwal follows photographer Edward Burtynsky as he visits china and documents landscapes and sites that have been transformed by human activity. Primarily, although not exclusively, these landscapes are the result of manufacturing activities, and include both outdoor scenes, as well as some indoor scenes. The film includes some voice-overs by Burtynsky, which range from simple descriptions of the scene, to some limited discussion of the politics of the scene, such as his view of how China is late to the "oil party". We can look at critical reviews of the film to see how these ideas are transmitted. Kenneth Baker of the San Francisco Chronicle writes that "the viewer soon realizes that [Baichwal] shares Burtynsky's astonishment and concern over the scale, tempo and irreversibility of postmodern humanity's global frenzy of production and consumption" and that it "leaves its audience with many troubling questions." [4] Janet Smith of straight.com writes, "But even though the artist insists he's "not trying to glorify it, nor am I trying to damn it", his photographs, and this film, speak of nothing but our impending doom in terrifying biblical scale." [26] Stephen Hunter, in *The Washington Post*, writes "It's all the more powerful for being silent in its accusation." [20] However, Manohla Dargis, of the *New York Times*, writes that "Whats missing from these photographs, those populated and not, is any sense of process, of context and consequence." [14] Expanding on Dargis's comment, we can consider that the way memes are presented by Burtynsky is ambiguous. The viewer has the opportunity to project their own viewpoint, in their own internal dialog and questions, in a way that is less available for, say, a work of physics. As Burtynsky states in a voice-over in the film:

If I said this is a terrible thing we're doing to the planet, then people will either agree or disagree. By not saying what you should see, that may allow them to look at something they

never look at, and see their world a little differently.

Other than presenting an abstract model, Congestion on its own does not say anything. Assuming a logical and structurally interesting model, we can say it has the potential to impact, by creating interesting ideas, the world of artistic science. And by presenting a blank, but beautiful, slate, it has the potential to create new memes, not by presenting them directly, but by allowing its viewers the empty space to create them on their own.

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