

Societal Path Integral¹

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Abstract. In the path integral formulation of quantum mechanics a particle moving from point **A** to point **B** is pictured as taking every possible path to accomplish this transit. The classical path is given the most weight and thus contributes the most, but every path makes some contribution. However, those paths which deviate more from the classical path contribute progressively less. In this essay I argue that in order to best steer society/humanity one should loosely adopt this quantum mechanical approach of trying “all paths”. Those societal “paths” which are judged best/classical would be given the highest weight in steering humanity forward.

CAN ONE STEER HUMANITY?

Before launching into the main thesis of this essay – that human societies should loosely emulate quantum particles as described by the path integral formulation of quantum mechanics – I briefly look at the present day ability of humanity to steer *any* course. I take “steer” to mean that humanity (or some subset of humanity) has decided to accomplish some task and then has the ability to move in the direction of making the goals of this chosen task a reality. For example, say Indonesian engineers (with the financial support of the government) decided to build a bridge across the Sunda Straits, connecting the islands of Sumatra and Java [1]. This is something which lies within the capability of people to do. And it is something which would be beneficial to humanity – or at least the subset of humanity which wants to more easily travel between Java and Sumatra. And it is something which 500 years ago humanity would have been incapable of doing. However, suppose that instead of building a bridge across the Sunda Straits that the task was to send a colony of people to some nearby star. Even using present or near future propulsion technology such a task would probably not be possible for humanity at present. First, doing a quick lower bound estimate of just the energy to accelerate a 10,000 kg payload up to 10% the speed of light and then slow down again once the destination is reached gives about 10^{19} Joules. The present annual energy use of the entire world is about 5×10^{20} Joules per year. This makes such an interstellar undertaking economically, as well as technologically, unlikely or impossible at present. Maybe in 500 years such task would be feasible. After all 500 years ago humanity did not have the resources and energy at its command to build a bridge across the Sunda Straits, but today it can contemplate such a task.

The ability of a society to harness a certain level of energy was used by the Soviet astronomer Nikolai Kardashev to categorize civilizations into three broad types – Type I, Type II

¹ Essay written for FQXi Essay context “How should Humanity Steer the Future?”

and Type III. Roughly a Type I civilization can control the energy resources at the level of its home planet, a Type II civilization can control the energy resources of its home star and solar system, and a Type III civilization can control the energy resources of its home galaxy. Carl Sagan interpolated the Kardashev scale to intermediate values using the formula

$$K = \frac{\log_{10}(MW)}{10}, \quad (1)$$

where K is the Kardashev value of the civilization and MW is the power it uses in megawatts. The point of this equation (other than pointing out that physicists have a hard time *not* putting equations in their writing) is that according to (1), and taking the world power usage as $3.7 \times 10^7 MW$, one finds that at present we are a $K=0.76$ Type civilization. Thus while there is plenty of reason to marvel at how far humanity and human society have come in the short time we have been around, nevertheless in the sense of the Kardashev scale and its implied control of the environment in terms of energy usage, we are really a novice civilization. And as with every novice, there is often not a great deal of control or ability steer where one wants to go. A beginning skier knows they are going to go down the mountain, but whether it's on the right side, middle or left side of the slope is often a mystery especially to the beginning skier. So too for humanity at the present time, it seems fair to say, has a limited ability to actively steer in a given direction.

To a large extent the course of humanity is shaped by events that are too large or too small for humanity to steer a course well or at all. By events that are “too large” I mean things like a 200 km diameter asteroid heading toward Earth, a nearby star going supernova, or the Sun sending out a super flare that happened to be directed at Earth (certain stars for not well understood reasons send out flares which extend a good distance through their solar system and would incinerate any planet it hit). The Kardashev scale shows that humanity at present has not reached a level of energy control to deal with the above situations or ones that require a similar manipulation of energy. In the case of the comet this is just a matter of size – if the asteroid were 2 km in radius there might be something humanity could do with sufficient lead time to deflect the asteroid. Phil Plait (a.k.a. “The Bad Astronomer”) has a recent, entertaining book on different ways humanity could meet its end via astronomical means [3] which include asteroid or comet impact, gamma ray bursts, solar flares, and nearby supernova. Although the Kardashev scale indicates humanity is still a novice civilization, we do have some limited ability to control our fate in term of situations which require a level of energy control at the level of the home planet i.e. $K=1$. But solar system or galactic level phenomena are beyond our ability to steer.

It is easy to understand why humanity might not be able to deal with events which are “too large” for our present Kardashev scale value, but what is meant by events that are “too small”? The meaning here are events which are initially overlooked and seem inconsequential, but which end up having a major impact on the course of human events. This is similar to the Black Swan Theory expounded by Nassim Taleb in [2]. The Black Swan idea revolves around the difference between *known unknowns* and *unknown unknowns* and the often large impact (both positive and negative) of unknown unknowns. Known unknowns are things like calculating the probability of winning in roulette or the probability that a quantum system will be in some specific energy state when a measurement is made. One does not know what the outcome of a single spin of the roulette wheel will be or what the result of a single measurement of a quantum system will be, but one can calculate very well the probabilities of the potential outcomes. On the other hand if in 1995 one wanted to calculate the probability that two Stanford graduate students would found a multi-billion dollar internet company (*i.e.* Google) based on doing searches of the

internet there is no way to honestly calculate such a probability. Or if in Europe of the 1680's one wanted to calculate the probability of finding a black colored swan, there is again no way to rigorously calculate such an event². Such events are small, at first, but in some cases (in the case of the founding of Google but not in the case of the discovery of a black colored swan) they can have a major impact on the development of humanity.

The above arguments are intended to show that humanity at present does not have a very significant ability steer its fate as it is carried through the Universe by the Milky Way Galaxy, the Sun and the Earth. But there are fundamentally unpredictable, “small” events which can have a large impact on the course of humanity. Such events, at least at the beginning, are within the ability of humanity to steer. In the rest of the essay I will give a suggestion as to how one might maximize humanities steering a path toward such unpredictable events which are positive.

A PATH INTEGRAL APPROACH TO SOCIETY

One of the ways of formulating quantum mechanics is the path integral method pioneered by Feynman [4] following an initial suggestion by Dirac [5]. In the path integral version of quantum mechanics a quantum particle in going from point **A** at time t_A to point **B** at time t_B is pictured as taking all possible paths leading from **A** to **B**, but with the each path being weighted by the exponential of $i \cdot \text{Action}/\hbar$. Then the probability of the particle to propagate from **A** to **B** is given by the *functional* integral

$$\langle q_B t_B | q_A t_A \rangle \propto \int Dq \exp \left[\frac{i}{\hbar} \int_{t_A}^{t_B} L(q, \dot{q}) dt \right]. \quad (2)$$

Here $S = \int L dt$ is the action, and the integration measure Dq is over all possible paths the lead from **A** to **B**. This may seem a very complicated way to solve quantum mechanical problems, but in fact this method offers some advantages and deeper insights in certain situations when compared to the canonical approach to quantum mechanics.

Here I want to use the path integral as a *loose* metaphor for suggesting how humanity can “best develop itself”. Just as a quantum particle tries out many different paths, so too humanity should try to sample different approaches as to how society could be structured. Then by appropriately weighting these different approaches and determining which approaches are best (or using the path integral language which societal paths are “classical”) move society in this direction.

The first thing to point out is that if one wants to try many different approaches to structuring society, this means first trying things out on a small scale. If one tries different paths on a large scale then one can try only a small number of paths. Thus one might miss a promising way to structure society. If on the other hand one funds many small scale projects there is a better chance one or more of these approaches will prove beneficial. For example, the Obama administration has given a government sponsored health care coverage plan to US citizens through the “Patient Protection and Affordable Care Act”. The key question about this health care plan should be “Is this the best possible health care plan?”. Certainly, Republicans and Fox News commentators would say it is not the best health care plan. One could do theoretical studies of different possible health care systems to try and determine which is best in terms of a

² In 1698 the Dutch explorer Willem de Vlamingh discovered black swans in Western Australia.

balance of cost efficiency, quality and timeliness of health care given, and other factors that are deemed important. But theoretical studies by themselves often miss subtle, unexpected consequences and outcomes especially for a complicated system like a health care system. Alternatively one could set up small scale health care systems (or more realistically study those systems in different states in the US or different countries around the world) to see which system or systems are best – or using the path integral metaphor – which system or systems are “classical”. By experimentally trying out many different health care systems on a small scale one should be able to find those systems which work best. The path integral prescription for ordering various aspects of society for the best is then, not to try a small number of large projects, but rather try many smaller projects. After having let these smaller projects make their search through the “phase space” of society one determines which of these small projects give the best results. Then move forward with implementing these successful small scale projects on a slightly larger scale, and then slight larger still until one has the best health care system(s) or whatever other aspect of society the small projects were intended to address.

The idea of advancing society to a better state by trying a host of small scale, projects rather than starting from the outset with a single massive, untested project is not original. In the book *Guns, Germs, and Steel* [6] one of the reasons advanced by the author Jared Diamond for the Great Divergence (the ascendancy, starting in the 19th century, of Western Europe and parts of the New World over the rest of the World civilizations in terms of technology and control of resources and wealth) was due to the balkanization of Europe into smaller nation-states which were often not on the best of terms with each other. Competition between the various nation-states forced the rulers of these nation-states to be open to trying different approaches to things. Granted, much of the effort was geared to figuring out better ways to make war on ones neighbors, but generally the situation in Western Europe in this period encouraged innovation in all areas of society on a small scale – the scale of the nation-states. When a successful answer to a societal question or problem was found by one nation-state this answer would be adopted by the other nation-states. Or if a nation-state was not quick to adapt and adopt the new technological, societal or economic paths that emerged from the trial and error testing of different “paths”, then it would soon cease to be an independent nation-state. An example of the need to lead rather than oppose innovations was the Haijin or “sea ban” imposed in China by the Ming and Qing dynasties. In an effort to deal with piracy the Chinese emperors curtailed maritime activities. Although this policy was not really effective in stemming piracy it did have the unintended effect of retarding economic development of coastal regions in China. The unrealized, potential economic development may have been beneficial to China.

In terms of scientific advancement there is a lot of support for trying as many different paths as possible in order to move forward. This was one of the themes of the brilliant book and documentary series *Connections* by James Burke. In the TV series Burke shows how a series of apparently disconnected, often small, discoveries and inventions lead to various aspects of the modern world. In the episode, “The Road from Alexandria”, Burke traces the development of radar and nuclear energy and nuclear weapons to standardization of precious metals for the purpose of trade in the ancient world. The connections are: (i) standardization of precious metals leads to trade between Greece and Persia, (ii) leads to the building of large commercial centers such as Alexandria with its library with Ptolemy’s star tables, (iii) which in the 14th century leads to European ship navigators using this astronomical data to kick off the Age of Discovery, (iv) leads to these navigators realizing that their compasses don’t point exactly due North, (v) leads to investigations into magnetism by William Gilbert, (vi) leads to investigations into electrostatics

by Otto von Guericke (and others), (vii) leads to the investigation of atmospheric electricity and the invention of the cloud chamber by Charles Thomson Rees Wilson, (viii) finally leads to the development of the Watson-Watt's radar and through the work of Rutherford on atomic structure (using the cloud chamber) to nuclear weapons and energy. The path that Burke traces may at first appear contrived and it leaves out the contribution of many other scientists and engineers, but the main point that many, small, apparently unrelated steps led to important discoveries about how the world works, as well as resulting in important technologies, is convincingly argued. Closer to the present one can find arguments that, in terms of scientific advancement, one should try as many different paths as possible. In a recent study [7] of the scientific impact of work by researchers awarded or not awarded NIH **R01** grants, it was found that there was virtually no difference in the scientific impact of those grants which were ranked Category 1 (excellent grants according to the grant reviewers and which therefore got funded), Category 2 (very good grants according to the grant reviewers but which just missed the funding mark) and Category 3 (fair or marginal grants as judged by the reviewers which also did not get funded). Grants in all three categories published about the same number of articles and received the same number of citations. Of course number of publications and citations are not great measures of actual scientific progress. However publications and citations are the metrics by which NIH judges grant applications and so even in terms of their own criteria there appeared to be little difference in the three categories into which NIH grant applications were placed. The solution to this is that one should as far as possible try as many of these different scientific paths as possible.

In summary, the proposal being advanced is that in steering the future direction of humanity one should emulate the path integral of quantum mechanics and try as many different paths as possible – paths here meaning different ways of structuring society, of having a health care system, of having a public transportation system, *etc.* Once a best (*i.e.* “classical”) path or paths has been determined one can try to scale up this path or paths. Now we turn to the question of how to weight these different societal paths.

HOW TO WEIGHT EACH PATH

In the application of the path integral to physics the weight of a given path is given by the exponentiation of the i time the action as shown in equation (2). In the application of the metaphor of the path integral to steer humanity how is one to weight the different societal paths? And how does one determine which path or paths are “classical” or best? It is at this point that the metaphor might be stretched a bit thin. First one needs to come up with a set of criteria as to what is considered good and advantageous for the given societal problem or task. To be concrete let me use the task of how one gets hot water for taking a shower. This is not such a grand question, but nevertheless an important one. Also if one wanted a weightier question one could ask how one supplies *clean* drinking water to society. But the question of supplying hot water will suffice to illustrate the point of how one gives weight to a path. There are three different modern paths to hot water that I am aware of. There is a central water heating system such as found in Moscow; there is the individual water heater method where water is heated in each house in a 200-300 liter water tank; there are the suicide showers and electric water heaters where the water is heated on the spot as it passes through an electrical heating element. There are also solar heating systems where water is passed through pipes inside panels which collect solar radiation thus heating the water. There is also the method of heating water used in some private Roman homes where water from a nearby source was heated by passing it over a log fire.

However, the solar heating of water is at present not very common (at least in the US although maybe it should be especially in places like California or the American Southwest) and heating by wood burning fires, *a la* some private home Roman baths, has already been found to be less than optimal when compared to the other modern options of providing hot water. Thus I will focus on the above three modern methods of delivering hot water. Having spent two 6-month research visits in Moscow I became aquatinted with many aspects of life in Moscow, including the centralized hot water system. In a word it was great. Always plenty of hot water, with decent pressure (at least in the apartments I rented). However for some 3 week period between May and September the hot water in your district would be turned off to clean the system. Muscovites had various ways to deal with this annual hot water hiatus: take cold showers or no showers for 3 weeks; go to the apartment of a friend or family member in a district that was not shut off; buy and install an individual house water heater or suicide shower. In short this central system was efficient and reliable except for 3 weeks out of the year when you did not have hot water. In contrast the individual home hot water heater tank, while less efficient than the centralized system of Moscow, does not have the inconvenience of leaving one without hot water for some 3 week period in the late spring or summer. The individual home hot water heating method is what I and most of suburban America use, since a centralized hot water heating system would be impractical in addition to the fact that Americans, unlike Muscovites, would not easily accept being without hot water for 3 weeks. One should mention that these individual home hot water units also require cleaning (as I recently found out) but even then one is not without hot water for anything approaching 3 weeks. Finally there are the suicide showers or “on the spot” hot water heaters which heat the water by passing it over a heating element immediately before it comes out the nozzle or the spigot. I encountered these quite a bit during a 6-month research visit to Universidad de Costa Rica in San Jose. Many places in Costa Rica had these on the spot water heaters since central water heating was not an option and individual hot water heating tanks were more expensive and took up more space which was often at a premium. These on the spot water heating systems had a higher power usage as compared to the individual home water tank systems, but overall used less energy. The power usage was very high when the water was flowing through the system, but once you turned the water off that was the end of the energy consumption. In contrast the individual home water heating tanks need to continuously keep the water in the tank hot, so that even though their power rating is less, in the end they use more energy since they run for longer periods of time. However as the name indicates suicide showers have safety issues, at least if installed improperly. I first encountered a suicide shower in a hotel in Quepos, Costa Rica on a weekend trip. After checking in to the hotel I went to take a shower and was stopped by the shower head which had a tangle of bare wires snaking around it and running away from it into the wall. It did not look safe at all. I went ahead and took a shower which turned out fine except every once in a while there was a tingling sensation coming from the water. Later when I asked about this experience my host at the Universidad de Costa Rica explained that for economic reasons many places used this on the spot method of heating water, and that when properly installed such systems were equally or more energy efficient when compared to the individual home water heating tank method. However, he also said that when improperly installed one could get a tingling sensation (or worse) when taking a shower.

The point of this mundane example of how to supply hot water to a society illustrates that when deciding on how to weight a particular societal path one needs to choose a set of criteria *e.g.* efficiency, convenience, safety, ease of implementation, *etc.* by which to judge any given path. This part of the societal path integral proposal is the most subjective and may lead to

different groups choosing different paths as best or “classical”. One group of people may weight efficiency higher than safety and thus opt for suicide shower heaters, while for a different group safety and convenience may carry a higher weight so that this group would opt of the individual home water tank heater.

CAVEATS AND CONCLUSIONS

The main thrust of this essay has been, that in so far as it is possible for humanity to steer a course, it can try to steer a best or “classical” course by at first trying out, on a small scale, as many different paths as possible. The loose metaphor used was that of the path integral where a quantum particle tries out *all* possible paths in moving from some initial point **A** to some final point **B**. There are of course many caveats to any program which seeks to use scientific or semi-scientific methods to address societal problems. First the “answers” to societal questions given by the above semi-scientific method should always be considered conditional and temporary. The same is of course true in regular science – all answers are conditional and temporary. The Standard Model of particle physics has as yet no known disagreement with experiment, yet no one will be surprised if there is some new result coming from the Large Hadron Collider which would require an overhaul of the Standard Model. The answers one obtains to questions about how to steer humanity should be considered even more conditional and temporary, since societies are much more complex systems than an individual quark or lepton. Also one cannot do rigorous experiments on societies to the same degree that is possible for quarks and leptons. For societies, as is *often* the case in astrophysics or evolution, one has to take the systems which are given to one naturally and try to draw conclusions based on these “natural” experiments. An example of such analysis of societal “experiments” is the book *Freakonomics* [8] which investigates such things as how to uncover cheating among sumo wrestlers, the connection between legalization of abortion and drop in the crime rate, and the economics of cocaine dealers as embodied by the question “If drug dealing is so lucrative why to most drug dealers still live with their mothers?”. While *Freakonomics* used statistical analysis to come its conclusions about the various social questions its authors posed, there was much criticism that the analysis was too simple and limited to support the conclusions drawn. In any case one needs to always consider as conditional the conclusions drawn in regard to societal questions which are approached from a scientific point of view. The second caveat is that it may not always be possible to scale up the small scale answers found to societal question via the proposed “path integral” method. As a simple example of how some systems do not always scale in a simple manner one can consider the 1950s science fiction film *Them!* about giant ants created by nuclear radiation that terrorize the New Mexico desert. The ants in this film are simply ants which are linearly scaled up versions of regular sized ants. However the science of allometry, which studies the complex relationship between the size, mass, shape, *etc.* of living systems, shows that such monster ants are impossible. Their giant sized exoskeleton would not be strong enough to support their increased mass. For the same reason an elephant is stockier when compared to a Chihuahua. As the mass of the animal increases the strength of the animal (as characterized by the cross sectional area of the bones/exoskeleton) must increase faster to keep pace. So too one must check that societal answers found at smaller scales will work on larger scales. The third and final caveat I touch on is the implementation of those good or “classical” answers to a societal problem found via the path integral approach. The implementation is the purview of the governments (elected or otherwise) of a given society. The approach presented here is semi-scientific in that one runs many small societal “experiments” and then, based on chosen criteria,

selects the best path or paths along which to steer ones society. The assumption is that the leaders of a given government are data driven and familiar, at some level, with the scientific method. In a recent experience I found this may not be the case. Every year the American Physical Society (APS) solicits a few members from each of its divisions and sections to go to Washington DC to lobby House members and senators to support science issues. This February I went as part of the Far West Section (California, Nevada and Hawaii) delegation of the APS to this annual lobbying event. On arriving the APS staffers briefed the representatives from the different APS sections and divisions about the many detailed issues that we might want to bring up when we visited the offices of the congress members from our region. There were a lot of detailed issues that we could cover and I felt I had not done my homework sufficiently beforehand since I knew very little about the *specific details* of the various science policy issues that were brought up. However, this did not prove to be a great draw back during the visits to the offices. The representatives of the congress members we met did not want to discuss details or statistics. What almost all were interested in were individual stories for the “story bank” of the congress member. The stories they were interested in were human interest stories dealing with individual people from their state or district which would illustrate some point they were trying to make to the electorate. This “cherry picking” of data is not scientific, but it does help them get re-elected (at least this is the perception of the congress members). On the other hand faceless data, while being more informative than individual stories, will not help congress members get re-elected, which palpably seemed to be the overriding concern. Thus even if good answers to societal questions are found via the path integral method proposed here or some other method, there still remains the unanswered question of if the people charged with enacting societal change (*i.e.* members of the government) will act on “classical” path proposals motivated by data rather than cherry picked human interest stories.

REFERENCES

- [1] Muhamad Al Azhari, "Plan to Build World's Longest Bridge a Small Step Closer to Reality", *Jarkarta Globe*, August 14th, 2009
- [2] Nassim N. Taleb, *The Black Swan: The Impact of the Highly Improbable* (Random House, 2007)
- [3] Phil Plait, *Death from the Skies! These are the Ways the World Will End* (Viking Adult, 2008)
- [4] R.P. Feynman, *Rev. Mod. Phys.*, **20**, 367 (1948)
- [5] P.A.M. Dirac, *Phys. Z. Sowjetunion*, **3**, 64 (1933)
- [6] J. Diamond, *Guns, Germs, and Steel: The Fates of Human Societies*. (W.W. Norton & Company, 1997)
- [7] N. Danthi, *et al.* "Percentile Ranking and Citation Impact of a Large Cohort of NHLBI-Funded Cardiovascular R01 Grants", *Circulation Research*, **114**, 302656 (2014)
- [8] Steve Levitt and Stephen Dubner, *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything* (William Morrow, 2005)