Climbing The Epoch Ladder : Exponential technological growth with respect to the singularity

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***Abstract*—This essay is written in accordance to what is required for the successful completion of the subject *Technology & The Future* (WM0908TU) given at TUDelft.**

I. Introduction

WHEN one looks at technology as an evolutionary process with a seemingly exponential growth rate, one could start to try and predict where it is heading, as well as do one's best to foresee what the implications of it would be at a certain position in time on society as a whole and even more distant future technologies. Making any type of accurate prediction is an arduous task and technology is no exception to that. Needless to say, there are certain technologies which are easier to predict than others, but the fact remains that one is dealing with uncertainties and models which might be wrong. In this essay certain specific views concerning technological progress is discussed. The focus is placed on what is known as *The Singularity* as defined by Ray Kurzweil [1]. The implications of it, as well as certain arguments against it is looked into and discussed. It has to be pointed out that even though some implications of the singularity are mentioned, the focus will not be on the implications itself. The focus will be placed more on the concept on which the singularity is based, i.e. the double exponential growth factor. In Section II the basic concept of the singularity is presented together with some background knowledge relevant to the topic. Section III discusses arguments for and against the singularity, as well as some interpretation about what has been stated concerning technological growth in general and specifically the singularity. An effort is also made to extrapolate the validity of the singularity occurring in the near future. The essay is ended with a conclusion in section IV.

II. Background and terminology

A. The singularity

The term Singularity is most widely known in the mathematical sense of the word, which describes the situation were a function is not analytic at a specific point or region [6]. An example of this is the function $f(x) = \frac{1}{x}$, which has a singularity at $x = 0$ which implies that as x tends towards zero, the function tends towards infinity and is thus not defined at that point. This type of singularity is not what is meant when used in a technological context. Numerous people have explored the singularity in the technological sense of the word including for example, I. J. Good, Ben Goertzel, Vernor Vinge, Kevin Kelly and Ray Kurzweil just to name but a few. There have also been conferences and broadcasts about the topic, for example the Singularity summit of 2006 and 2007 and BBC coverage on the subject. Ray Kurzweil defines the singularity in his book [1] as

> *...a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed.*

In an online article [2] Kurzweill clarifies what he exactly means with the metaphor implied by the term singularity.

> *...the term "singularity" as applied to future human history is not to a point of infinity, but rather to the event horizon surrounding a black hole. Densities are not infinite at the event horizon but merely large enough such that it is difficult to see past the event horizon from the outside.*

Kurzweil wrote the above mentioned article in response to an essay written by Kevin Kelly entitled *The Singularity Is Always Near* [4]. Kelly disagreed with the singularity idea as a discreet event for a few reasons which were summarized at the end of his essay.

> *The singularity is not a discreet event. It's a continuum woven into the very warp of extropic systems. It is a traveling mirage that moves along with us, as life and the technium accelerate their evolution.*

What is meant with the singularity seen from these statements is thus not a single discrete event, but more a period where technological change will be so extremely rapid, that it has very dramatic implications. Rodney Brooks also gave a talk about this viewpoint that the singularity is not a single event but more a period at the 2007 Singularity summit [13]. Some of these radical implications have been explicitly mentioned by advocates in the field. The following list is some of the predictions made concerning the result of this extreme technological growth.

- The merger of biological thinking and existence with technology. [1]
- Humans becoming vastly smarter due to this merger. [3]
- This merger will also result in the new evolutionary process of technology. [3]
- Eventual radical life extension, through the integration of human and machine. [1]

This is but a very short list of numerous things which have been stated, but as can be seen is that if it would to be realized, it will have dramatic implications on technology, society and the whole of human existence. This explains why there is such a big interest in it the last few years. Kurzweil is one of the biggest advocates of the singularity theory, and in this essay his viewpoint of the singularity is seen as a working definition, and will be explored in that context.

Kurzweil bases his theory of the singularity on a concept known as *the law of accelerating returns*. This concept has to do with the growth of technology and the rate at which it happens. The following subsection describes this concept in more detail with specific reference to [3].

B. The law of accelerating returns

The law of accelerating returns is a concept which describes the acceleration of the pace of the exponential growth of the products of an evolutionary process. The following is a summary of the key points concerning this idea.

1) Evolution applies positive feedback: the more capable methods resulting from one stage of evolutionary progress are used to create the next stage.
2) Due to positive feedback the rate of progress of an evolutionary process increases exponentially over time.
3) A second level of exponential growth results: the rate of exponential growth itself grows exponentially, examples of this is biological evolution and technology evolution according to Kurzweil.
4) A specific paradigm provides exponential growth until the method exhausts its potential. When this happens, a paradigm shift occurs, which enables exponential growth to continue.

In his book [1], Kurzweil states a number of examples of technologies which are subject according to him to the law of accelerating returns (i.e. having a double exponential growth rate), and what it might mean and the results of it. The following is a list with some of these examples.

- It is information technology (IT) which has a predictable trajectory.[14]
- Exponential growth of computer hardware, ex. dynamic random access memory (DRAM), microprocessor clock speed, processor performance (MISP) etc.
- Recently biology can be defined as information technology. Kurzweil makes for example the predication [14] that we will be able to simulate all the regions of the brain within 12 years or less, and that it will take approximately half a century before artificial intelligence (AI) will pass the Turing test.

One of the key issues concerning the *law of accelerating returns* as stated in [1], is that at a point where some technology is saturated, innovation turns the S-curve of any specific paradigm into a continuingly exponential.

There have been numerous critics as well as acceptance of the concept of accelerating returns of whom Kurzweil and Smart are of the biggest advocates, and Huebner and Modis are of the most known critics. The following section continues this idea concerning technological growth and provides some of the viewpoints and their underlining trail of thought.

III. Discussion

Recently the singularity summit 2007 was held at the Palace of Fine Arts Theater in San Francisco California. There were numerous speakers of which Peter Norvig, CEO of Google, was just one of many. In his talk [7] at the summit he started of with a statement which I found interesting and worth mentioning here. He referred to two contradictory statements made by two important figures on the subject of future predictions. He was referring to the viewpoint of Steve Kirsch who stated that humans will be extinct within 90 years because of climate change, and the other statement of Aubrey de Gray who predicts that he himself will be living until he is 3000 years old by slowing down the aging process significantly. These predictions cannot both be right, and leads to the point which Norvig wanted to make, and which I also want to state here. When one is confronted by all kinds of technological predictions, which one should be believed and which one should be discarded?

An inherent problem with predictions about technology is that there are always certain assumptions made when conducting the prediction. This may also be unknown to the person making the prediction, which makes the processes even more uncertain. One could argue that the predictions are made on basis of some data obtained over years, but the fact remains that the data itself may contain assumptions when being realized. For instance the curves concerning the important events in history, which are used to extrapolate the exponential curve of technology growth, has the inherent assumptions about which events are important and which are of lesser importance. Who gets to make this decision, to determine which events are important and which are not. An even more crucial point is what kind of criteria is used to make these decisions? This I have seen is a recurring theme when discussing technology prediction in general, the fact that people base some of their predictions not only on fact but also on assumptions. This will unfortunately be no different in this essay when certain views are investigated. I also had to make some kind of assumption sometimes to be able to continue with a certain analysis. This is not always detrimental, but one should just always be cautious of that fact and bring that with in the calculation when making any conclusion.

In this section I elaborate on the key issue on which the singularity is based, namely *the law of accelerating returns*. This is done by looking into some of the implications of it, together with some arguments against this type of viewpoint. I also interpret these different viewpoints and try to see some validity in it all.

I begin the discussion by investigating the acceleration of technology growth by using the Nobel prize as benchmark.

This example illustrates my point concerning the difficulty one faces when trying to say something about technology growth by investigating and interpreting data. After that, the concept of using patents as a technological unit is discussed. This section is ended with some of my own thoughts and questions concerning the singularity and predicting technological growth in general.

A. Nobel prize as a benchmark for technological progress

The Nobel prize is given every year to some individual or group of individuals whom have independently or together made a discovery of significant proportion. In this essay only the Nobel prize in physics and in economics are investigated. There is some assumptions in this analysis which are as following.

- The Nobel prize is given for a discovery which had a truly significant impact on technology or society.
- The Nobel prize committee and the people making the nominations are well aware of research and discoveries and their impact on technology and society respectively.
- That technology comes forth out of science. [1]
- If technology were accelerating or decelerating it would be evident in the Nobel prize laureates ages or time difference between discovery and Nobel prize. What is meant is that the rate for discovery and rate of winning the Nobel prize would also be accelerating or decelerating. I am not stating that they would necessarily have the same rate, but there would be some acceleration or deceleration in the time between making the discovery and winning the award.

A list of nobel prize laureates in Physics and the year in which they approximately did their work and the year in which they got the Nobel prize [8] were used in this analysis. In all the figures presented here the lines in between the data points are just there to make it easier for the reader to look at, and do not have any other significance. In the case were there were more than one person who were awarded the Nobel prize, the oldest person's birth date was taken as reference. The reason for this is that one wants to see how long it takes from date of discovery to the date of Nobel prize awarded, and thus the younger person could have used the other person's knowledge already when making his contributions. When it was unsure when the person approximately made the discovery, the Nobel prize for that year was left out of the data which were analyzed.

Figure 1 depicts the time difference between the approximate time the discovery was made and the date on which the Nobel prize were awarded to the respective people. The basic idea of this analysis was to see if there is any type of acceleration in the time between a discovery and a major impact on society. Here the major impact on society is embodied in the Nobel prize. This means that if there is an acceleration in the time between making a discovery and impact on society, one might see a shortening in the time between discovery and being awarded the Nobel prize. As one can see, there is no trend. One cannot indicate any growth or decline between the time of discovery and time of Nobel prize awarded, i.e. one cannot fit any exponential function to the data.

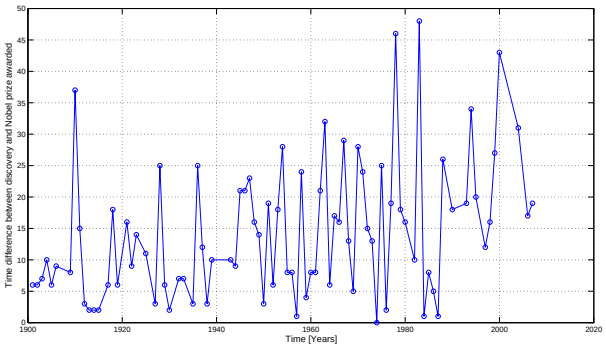

Fig. 1. The difference between when a discovery was made and when a person won the Nobel prize in Physics

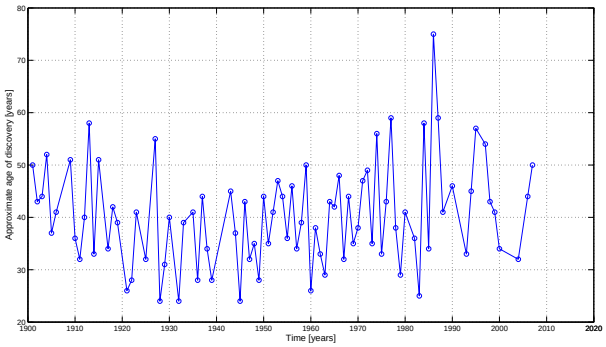

Fig. 2. Age of a person when a specific discovery was made which won him/her a Nobel prize in Physics

Inherent to this analysis is the fact that the person (or group) had to be elected by the Nobel prize committee in a specific time. It could have been that the committee saw the impact on society (or technology) a bit late [2]. To try and compensate for this, I subtracted the date of birth as stated in [10] form the date on which the discovery was approximately made as stated in [8]. Figure 2 depicts the result. This should be indicative of whether there is a decrease or increase in the amount of time between birth and discovery. As can be seen from the data, there is no exponential growth of this time difference.

It was possible that this was just an coincidence related to the Nobel prize in Physics. To investigate if any other of the fields also showed no real growth or decline I also investigated the Nobel prize in economics in a similar way. I took the date of birth of each individual and subtracted that from the date on which the person got awarded the Nobel prize. This thus gives an indication of the time it takes between someone making a discovery and the time

[1] This is not always the case as clearly stated in [9], but can definitely be a good indication in our day and age.

[2] I am not insinuating that this really happened, but I am just hypothesizing to see were it is leading

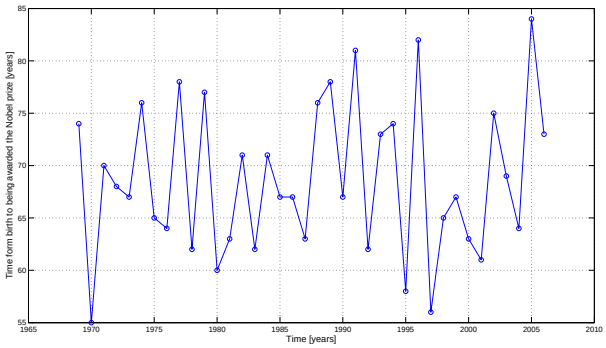

Fig. 3. Age of a person when he received the nobel prize in economy

it takes before its impact is clearly visible by a external person (or group) not directly influenced in the field. Figure 3 depicts the result. This also didn't display any explicit growth or decline and depicted similar results than that which were obtained with the analysis of the physics nobel prize data.

I unfortunately do not have one straight answer to the above displayed results. One possibility could be that the amount of data are just not enough, that we need more time so see if a growth appears. Another possibility is that there might be an increase of complexity of the discoveries and one would then expect to see a shift in the avergae age. This is a topic which was indeed investigated by Benjamin [15],[16]. Benjamin investigated the phenomena that the age at which a person makes a contribution is rising. In [15] he used the data on Nobel Prize winners and great inventors and concluded that the mean age at which noted innovations are produced has increased by 6 years over the 20th Century. His conclusion is thus a bit different than mine, both using approximately the same data. This then is one example of where the data can be a little ambiguous when looked at in different ways. I myself investigated the growth trend to find any type of curve which indicated a constant increase or decline in the age, and Benjamin investigating the mean average increase or decrease. He continued on this investigation of declining innovation rate in [16], where he focused on something which he called *Knowledge burden*.

Knowledge burden according to Benjamin is the occurrence of more complex innovations with the implication that people take longer to reach a level where they can contribute significantly to a field. The knowledge burden according to Benjamin implicates that the

> *...nature of innovation is changing, with negative implications for long-run economic growth.*

Benjamin used some patent data in his analysis, which indeed showed some increase in the amount of time before an inventor makes his or her first contribution. The increase had an approximate slope of 0.06 age of a person/year. This is not an extremely high slope of increase, but an increase all the same. In the next section I will elaborate about the topic of using patent data to make predictions about future technology. Different people's viewpoints are presented and interpreted slightly.

B. Patents as basic unit of technology

Patents can be seen as the basic unit of technology as stated by Huebner in [5]. In his paper he showed a graph of the rate of invention in the United States (US) since the Patent Office opened in 1790 until 1995. The rate of invention is defined there as the number of patents issued each year to US residents by the US patent Office divided by the US population. The choice of defining it in this way, according to Huebner, is to avoid problems when including the world's population with using development countries were there might be a rapid growth but have very little contribution to technology advancement. In one of the figures in his article he indicated that the rate of invention defined as just stated peaked in 1916 and afterwards had a overall trend of decrease. He used this as evidence that there is an economic limit (economic limit is seen equivalent to economic feasibility) of technology being approached, since the rate of invention in the US closely resembles a bell curve rather than an exponentially increasing curve. He states that this decline in innovation is most likely due to an economic limit of technology or a limit of the human brain that we are approaching.

This specific view of patents as done by Huebner has been criticized by John Smart in [12]. Smart stated for instance that looking at more recent data (for example up to 2003) indicated that patents per capita are back up to 95% of the 1914 peak. He also criticized Huebner's idea that patents can been seen as the basic unit of technology. He states that

> *...I find them to be mostly a measure of the kind of technology innovation that human consider defensible in particular socioeconomic and legal contents, which is a crude abstraction of what technology is.*

Smart is also an advocate of the idea that humans shall integrate with machines in the near future. This is a viewpoint which has to be taken into account when one makes a statement like that of Huebner that humans might reach the limit of the human brain, since it has direct implication to our limit of innovation and technology growth. Despite the criticism, Huebner mentioned some interesting questions in his article which are worth stating here. In this essay I only state two of these questions which I think are relevant, but the reader is referred to [5] for the complete list.

- Are improvements in the flow and processing of information the primary sources for increases in the rate of innovation?
- Will the level of technology reach a maximum and then decline as in the Dark Ages?

These questions don't have one definite answer at present, one expert in the field will give you his or her answers based on his or her findings and knowledge, and another person something else as was indicated by the statement of Norvig at the beginning of this section. The questions as stated here are meant to be indicative of the convoluted problem at hand, and stimulate thought as they did in the paper by Huebner. There

is a chance that the improvement in the flow and processing does indeed increase the rate of innovation, but whether that is the primary source is very difficult to say. But if we go out from that point of view, that the improvements in the flow and processing of information is indeed the primary source, then due to this improvement of flow it might reach a point of saturation, and thus be faced with a limit in innovation. The primary source of our innovation has at that point reached a limit, which might indeed very well result in a decline of technology as asked in the second question. Thus, there is a possible correlation between the two questions asked, which make them even more difficult to answer. Answering any of these questions precisely without speculation is very hard and won't be discussed further here. They are pure to stimulate the thought process and indicate the difficult situation which one is in when dealing with these types of questions. The following subsection concludes this section and combines the ideas presented with a slight interpretation from the author into stating whether one could with any certainty expect the singulary very soon.

C. Validating the singularity

Different standpoints on the subject of technological growth have been given in the preceding paragraphs. The difficulty of interpreting, or at least validating any prediction have been shown and underlined. This can also be formulated as follows. If it were in any way possible to predict the future of technology very accurately there would have been no discussion of this sort at all. This is (un)fortunately[3] the case when one starts to investigate the opinions of the futurists concerning the development of technology. Norvig also stated a similar argument [7], which pointed out that experts do not necessarily have the best view concerning a technology forecast, and that people outside the field can be just as adequate and sometimes even have much better predictions due to their overview.

The data concering the Nobel prizes and patents have been shown and indicates that there is a possible decline in innovation, while other data have shown a definite exponential increase. Kelly states [4] that there is even a chance that we don't notice the so called singularity happening, but only remark it in retrospect. This in my opinion is unlikely since we are already aware of the possibility that technological growth may accelerate rapidly and have extreme results. I also think that we will notice if technology changes quicker, as well as if it starts having greater impact on society. A definite statement or some form of probabilistic figure indicating whether or not the singularity is an inevitable truth, is to my current knowledge unknown. More investigation has to be done to get a clearer view of all the factors which play a part.

IV. Conclusion

In this essay the concept of exponential growth with respect to the singularity has been explored together with some arguments against the concept of technological growth. Niels Bohr apparently once said

> *It's hard to predict, especially the future.*

This I think is a key issue to keep in mind when evaluating any type of prediction made, thus to remain sceptical and not to believe something which is based on some real "measurable data" without thorough investigation of the underlying assumptions and theory. The above arguments all might seem quite valid under certain circumstances and assumptions, but all are based on data which might already contain some errors, which could possibly propagate through the analysis process undetected, and result in erroneous predictions. An important issue which has not be dealt with in this essay which is also relevant to evaluating predictions in my opinion has to do with paradigms. The following quote from Henry Ford describes it best.

> *If I had asked people what they wanted, they would have said faster horses.*

It has to do with the fact that people always think in a certain paradigm and that holds back creativity but also acceptance of new and radical ideas, this is also the case for engineers and inventors which is know as the technical framework [9]. This has been a phenomena in all ages of man, and is also still present today, and my viewpoint concerning the topic of the singularity is not any different. The important point is that the relevance of someone's opinion towards any topic in general should be to a certain extent weighted in this manner. It should thus be kept in mind what background and interests the person has when one validates their predictions. With this in mind it is extremely difficult to say, as stated in the previous section, with the limited knowledge whether the singularity will really ever happen or not. It is very confusing when one consults the experts in the field. Ray Kurzweil for example thinks that it is very probable [1], while Vernor Vinge [18] doesn't think the chance is that big. And then there is the view of De Garis [17] who has a very pessimistic horror kind of vision of the singularity and all its extreme technological changes if it occurs with terrible outcomes for human kind. There are definitely certain evidence which point towards it occurring, or at least some period of rapid technological change, but there are also some other evidence which indicates the opposite. The best way to approach it at present I believe, is to wait a bit longer and see what happens in the next few years. If the growth is of the extreme proportions as which are predicted, we should be seeing their influence quite soon...

[3]Whether to know the future or not can be fortunate as well as unfortunate

Acknowledgment

The reader should remark that what is presented in this essay is in no way complete. There is a mass of information to be found concerning technological growth specifically but also the singularity in particular. This essay discussed some ideas which are relevant to the subject, but much more research is needed to give any type of valid supported opinion.

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