Utilizing Future-Viewing Instruments

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The concept of *future-viewing instruments* is examined in detail. This term refers to devices which, under some circumstances, could allow users to directly observe future scenes. It is shown that such a technology would enable systems of intertemporal data exchange without any possibility of paradox or "auto-generated information" [1]. Instruments of this type could lead to the founding of an intertemporal Internet. Working out how they could be invented and constructed are matters left for the reader.

1 Introduction

The idea of instruments for viewing future scenes appeared in fiction as early as 1924, and this concept was introduced to millions of television viewers in the 1960s [2–4], but it has yet to be thoroughly examined in academic circles. On the other hand, the related concept of travel to the past has received considerable attention from scientists and philosophers, especially in recent decades. Here, the logical dimensions of future-viewing instruments will be explored and then contextualized in terms of what has been learned about the logical dimensions of time travel. With this understanding it becomes possible to entertain ideas about how future-viewing instruments could be utilized.

Tales of mystic seers abound in myths from ancient cultures. The ancient Greeks told of Cassandra, princess of Troy. In her youth, she and her brother gained the gift of prophecy during an overnight stay in the temple of Apollo. After she grew to become a beautiful woman, Cassandra spent another night in the temple. Apollo then appeared to her and sought intimacy. She refused him, so Apollo cursed Cassandra. He decreed that her prophecies would be disbelieved; thus, the seeds of tragedy were sown. Cassandra warned that warriors hid in the wooden horse, but she was thought a lunatic [5].

Although the concept of individuals who are able to access future scenes in personal visions is directly relevant to the topic at hand, it will not be discussed further here. The focus instead will be the concept of technological instruments that normal individuals could use to see into the future. A person who controls and monitors a future-viewing instrument will be referred to as its operator.

To begin, it is necessary to isolate an appropriate concept of future-viewing instruments. What kind of device would be both useful as a future-viewing instrument and logically possible? The analysis must start with consideration of a foundational issue—information. The future is unknown to us. Information about any set of unknowns may be either definite or ambiguous as well as correct or incorrect.

Thinking about a playing card concealed in a box, consider an example of definite information about it: "The card in the box is the queen of hearts." Definite information which also happens to be correct, of course, is the most useful. One might instead receive ambiguous information: "The box contains some card in the suit of hearts." Correct but ambiguous information might also be useful. However, when vague information approaches maximal ambiguity it becomes so nonspecific that it is guaranteed to be correct, rendering it useless.

In considering possible types of future-viewing machines, a maximally ambiguous device might be imagined. Such a device would display every possible happening associated with a given selected set of future spatio-temporal coordinates (x, y, z, t), but it could not highlight what will actually happen. Devices of this type are here termed *Everett machines*, referencing physicist Hugh Everett III's influential 1957 "relative state" interpretation of quantum mechanics [6].

Being maximally ambiguous, Everett machines would be useless as future-viewing instruments. They are unable to tell what will occur among everything that might occur at any set of future coordinates under examination; in a term, they are not *outcome-informative*. For this reason, Everett machines cannot be classified as future-viewing instruments. Outcome-informative devices have the ability to provide definite and correct information about future events, at least in some cases.

How powerful could a future-viewing instrument possibly be? Composite devices such as have appeared in fiction, which somehow have agency and the means to force their own prophecies to come true, must be excluded from consideration.* Future-viewing devices which are only capable of gathering and displaying information will here be termed *inert future-viewing instruments*. Given this important refinement, the following question may be asked: How powerful could an inert future-viewing instrument possibly be?

To answer this question, the maximal case is explored. Consider an inert future-viewing device which is always able to provide definite and correct information about all future outcomes in every possible circumstance of attempted future-viewing. These hypothetical devices for exploring the maximal case are termed *Cassandra machines* after Cassandra's tragic helplessness in averting the calamities she foresaw.

It will be shown that Cassandra machines, as defined, are not logically possible; no inert device could provide definite

*It would appear that Serling's most unusual camera can occasionally exert diabolical control over those who end up in its pictures of the future [3].

and correct information about all future outcomes in every possible circumstance of attempted future-viewing. A single counterexample situation is sufficient to prove this. This situation will emerge as one mode of a future-viewing experiment involving three randomly selected modes. The experiment will be built up in stages; the counterexample mode will be presented at the end.

Begin by imagining an experimental setup consisting of an inert, though otherwise arbitrarily powerful future-viewing instrument (FVI) and a computer. The computer is constantly being fed a string of ones and zeros from a random number generator (RNG). The RNG contains a radioactive sample connected to a sensitive Geiger counter. The pattern of ones and zeros the RNG produces is a function of the output of the Geiger counter, so no known prediction methodology could predict the sequence produced.

The computer will use an algorithm to process one second of the sampled output of the RNG to arrive at a whole number in the range 0 through 99. This number will be displayed on its large and bright, two-digit readout.

Many kinds of algorithms can be used to determine a whole number, within any desired range, from any finite set of ones and zeroes. For instance, in order to arrive at a whole number in the range 0 through n, divide the number of ones in the set by $(n + 1)$ to find the remainder. With complete division represented by a remainder of 0, the remainder will always be a whole number in the range 0 through n.

Here is a simple two-step experiment involving these systems. Each step lasts one minute. At the start of step one, the FVI will attempt to future-view the computer's two-digit readout as it will appear in the middle of step two, i.e., a minute and thirty seconds later. When step two arrives, the computer will sample one second of the RNG's output and, by dividing the total number of ones in the sample by 100 to find the remainder, it will arrive at some whole number in the range 0 through 99 for display on its readout. This number is calculated and displayed within a few seconds and it will remain displayed throughout step two.

It should be no surprise that a properly functioning future-viewing instrument (in this situation) would always be able to correctly show, during step one, the whole number that the computer will interpret from RNG data and display on its readout during step two. An unpredictable process alone does not render the final outcome any less visually apparent when it arrives, and there are no logical barriers here.

Now, another system is added to the experiment. A character recognition system (CRS) is placed between the FVI and the computer. The CRS receives input from its camera which is pointed at the FVI's display. During step one, the CRS will recognize any computer readout digits it finds on the FVI's display and will assign the corresponding number as the value of the variable 'z' to be stored in its memory.

The critical detail which allows the counterexample to emerge in this expanded setup is that the computer has the ability to temporarily connect to the CRS and retrieve z. Here is the full experiment, encompassing all three modes:

As before, a two-step protocol is followed and each step has a duration of one minute. Before each run, the computer uses RNG data to reset its readout to some whole number in the range 0 through 99 to establish a preliminary value. Then, at the beginning of step one, the FVI attempts to see what number will be displayed on the computer's two-digit readout in the middle of step two, a minute and a half later. If the FVI is successful in receiving an image, the CRS will recognize the number in the image and store it as z. If the FVI does not receive an image, the CRS will revert to defaults and assign 0 as the value of z.

At the beginning of step two, the computer will sample one second of RNG data and process it to yield a whole number in the range 0 through 2. This selects one of the following three programs for the computer to run immediately:

P_R: Sample one second of the RNG output, interpret as a whole number in the range 0 through 99, display the result on the readout, then halt.

P_0: Connect to the CRS and retrieve z, then disconnect from the CRS. Halt if the number on the readout equals $z + 0$, otherwise change the readout to display a number equaling $z + 0$, then halt.

P_1: Connect to the CRS and retrieve z, then disconnect from the CRS. Halt if the number on the readout equals $z + 1$, otherwise change the readout to display a number equaling $z + 1$, then halt.

In each of these cases, the computer will finish all tasks and halt within a few seconds. In any kind of run, the FVI is involved in an attempt during step one to receive a signal containing an image of the *post-halt value* that the computer will display during step two.

Consider what would happen in a series of experiments using this expanded setup. In any P_R-mode run, although the z-value has been ignored by the computer, subsequent comparison will reveal that it matches the generated post-halt value. Consistent matching in P_R-mode runs confirms the instrument's basic functionality.

Next, in any run selected as a P_0-mode run at the outset of step two, the z-value encoded by the CRS during step one will also always be correct. It must be. After all, z has been retrieved from the CRS and $z + 0 = z$. So, the post-halt value in P_0 runs comes from the z-value, but where does the z-value come from? It comes from the post-halt value. So, another question must be asked: What determines the value itself? This is the purpose of resetting the readout to a preliminary value before step one. In every run that will turn out to be a P_0-mode run, the FVI will detect a post-halt value equal to the preliminary value. In P_0-mode runs, although any z-value at all encoded during step one would end up on the computer's readout in step two, only the preliminary value is non-arbitrary. So, even though P_0 follows the form of a self-fulfilling prophecy, the z-values encoded during step one of P_0-mode runs are still recognizably genuine prophecies since the mode of a given run is not decided until step two.

P_1-mode runs, however, would produce a very different kind of result. If RNG data will select P_1 at the beginning of step two, no z-value whatsoever encoded during step one could correctly identify the post-halt value that will be displayed on the readout, since $z + 1 \neq z$. In P_1-mode runs, it is impossible for any z-value to be correct; the z-value and post-halt value in P_1-mode runs will never match.*

This establishes that no device whatsoever could fulfill the definition of a Cassandra machine: Inert devices which would be able to provide definite and correct information about all future outcomes in every possible circumstance of attempted future-viewing are not logically possible.

So far, two kinds of hypothetical devices have been described; they are Everett machines which would not be useful as future-viewing instruments and Cassandra machines which are not logically possible. Eliminating both of these imagined conceptual options helps to identify an appropriate concept of future-viewing instruments.

For further understanding, it must also be recognized that any device which could ever provide incorrect (i.e., misleading) information regarding future events cannot be a future-viewing instrument. This is due to the important distinction between viewing future events directly, which cannot involve guesswork, and merely generating predictions about future events, which must involve guesswork. Visually accessing veridical foreknowledge is unlike the uncertain process of generating predictions.

Upon the above analysis, three features of any future-viewing instrument of an operationally coherent description may be specified: (1) Such an instrument must be outcome-informative, unlike an Everett machine, (2) it must be logically possible, unlike a Cassandra machine, and (3) it must be incapable of providing incorrect (i.e., misleading) information about future events. Devices which satisfy all three requirements have been termed *foreknowledge instruments*.

Foreknowledge instruments could be used to gain definite and correct information about future outcomes in a wide range of circumstances corresponding to P_R-mode and P_0-mode runs within the RNG experiment. Definite and correct information about future outcomes obtained from foreknowledge instruments will be termed *viewer foreknowledge*. Since foreknowledge instruments cannot misinform, definite information about future states obtained from foreknowledge instruments will always prove to be correct. So, it would be possible to recognize viewer foreknowledge upon reception. However, as the RNG experiment demonstrates, viewer foreknowledge would not always be accessible.

*The post-halt value in P_1-mode runs will always be 1. This is because the CRS will not detect anything from the FVI, since the FVI cannot acquire a signal; so, the CRS will revert to defaults and assign 0 as the value of z.

Situations exemplified by P_1-mode runs, wherein future-viewing cannot occur, are here termed *interference viewing situations*. Viewer foreknowledge would only be accessible within *non-interference viewing situations*, exemplified by runs of the two non-interfering programs, P_R and P_0.

2 Time machines and foreknowledge instruments

Time travel to the past will be referred to as *pastward time travel*. Pastward time travel and future-viewing are intimately related, for each could be used to acquire information from the future. So, if pastward time travel and future-viewing really are coherent concepts, they should be found to naturally cohere within a single conceptual context.

Serious interest in pastward time travel began when Kurt Gödel proved in 1949 that the equations of general relativity permit pastward time travel situations [7]. Extensive technical details concerning how time travel or future-viewing might be achieved within the framework of general relativity, or any other, are not needed here. The aim of this section is to explore the logical dimensions of pastward time travel, not how it might be achieved. Furthermore, it would not be appropriate to limit a discussion of the logical dimensions of time travel to any theoretical framework.

Conceptually, relocation may be achieved by continuous movement between spatio-temporal points, i.e., translation, or by what will be termed *discontinuous relocation*. Translation is familiar to everyone. Discontinuous relocation will here be defined as a process whereby a vehicle, for instance, is made to disappear from one location and reappear somewhere else, either a moment later or in a different time period altogether, even much earlier. Whether discontinuous relocation could be achieved, and how it could be achieved, are irrelevant considerations. For the current discussion it is merely necessary to recognize that discontinuous relocation is a logically possible mode of travel (i.e., relocation).

Since translation and discontinuous relocation exhaust all possibilities for relocation in space and time, it is possible to obtain exhaustive conclusions about the logical dimensions of time travel without referencing any further specifics about how time travel might be achieved. This allows the argument to be conducted without tying it to any theoretical framework.

The central issue in any discussion of the logical dimensions of time travel concerns whether past-alteration paradoxes, which are so popular in fictional treatments of the subject, could ever be actualized. An extended argument will establish that it is not possible for changes to the past and accompanying paradoxes to result from the accomplishment of pastward time travel, no matter how accomplished. This argument will begin by referencing methods of pastward time travel based on translation, such as exist in general relativity. A simple extension of the argument will additionally show that paradoxes could not result from any form of pastward time travel based on discontinuous relocation.

The arguments of this section will explore time travel and future-viewing as conceived within a single timeline, since multiple-timeline models of time travel inherently sidestep any possibility of paradoxes. For instance, under a multiple-timeline model, if a time traveler were to go back in time and successfully prevent his parents from meeting, his own birth would remain safely unaffected in his origin timeline. Only time travel from a given timeline to its own earlier periods has ever been thought to offer any potential for paradox, so multiple-timeline models are safely ignored here.

Fiction has distorted our perceptions about time travel. It will be shown below that events which have happened one way without time travelers cannot somehow be made to happen again, but differently, if time travelers would ever happen to visit that time and place. While stories based on such absurdities can be entertaining, the misconception that the practice of time travel might ever actualize revisions to the past has been termed the "second-time-around fallacy" [8]. The following quotation from philosopher Larry Dwyer provides a sensible way to think about pastward time travel:

> If we hypothesize that *T* pulls levers and manipulates a rocket in 1974, and travels back in time to the year 3000 B.C. then of course, even before *T* enters his rocket, it is true that any accurate catalogue of all the events on earth during the year 3000 B.C. would include an account of *T*'s actions, reactions and mental processes. There is no question of the year 3000 B.C. occurring more than once. [9]

Although theoretical considerations related to achieving pastward time travel are not needed in the present discussion, some operational concepts are helpful for purposes of visualization. Imagine a device which is able to open hyperdimensional tunnels to past, present, and future spatio-temporal points. Travelers who would pass through such tunnels could travel great distances or achieve time travel to any connected era, and be retrieved. The device would remain stationed in the laboratory throughout.

This way of visualizing time travel by translation is found in the colorful literature of general relativity. Solutions of Einstein's field equations which describe hyperdimensional tunnels have existed since 1916, though travel concepts were not part of the early work in this area. Physicist Ludwig Flamm discovered solutions describing such tunnels shortly after the publication of general relativity [10]. These structures were further explored by Hermann Weyl in the 1920s [11]. Then, in 1935, when Albert Einstein and Nathan Rosen attempted to formulate solutions of Einstein's field equations free from singularities, they were also led to such structures: "These solutions involve the mathematical representation of physical space by a space of two identical sheets, a particle being represented by a 'bridge' connecting these sheets" [12]. These connecting structures came to be known as Einstein-Rosen bridges. In 1955, physicist John Wheeler named them "wormholes" [13].

In 1969, Homer Ellis and Kirill Bronnikov independently solved Einstein's field equations to describe gravitating, two-way traversable wormholes, and their works were published in 1973 [14, 15]. These ideas led to an understanding of wormholes of a kind that would be appropriate for travel, time travel, future-viewing, and past-viewing. These structures are non-gravitating, two-way traversable wormholes known as Ellis wormholes [16]. In 1988, Kip Thorne, Mike Morris, and Ulvi Yurtsever independently derived such structures and added important details to the discussion [17].

Two years later, these physicists co-authored an influential paper with Igor Novikov and three other physicists which suggested a "principle of self-consistency" would unfailingly govern pastward time travel situations [18]. Novikov began the tradition, at least in physics literature, of time travel free from paradoxes in a co-authored 1975 work [19].

Returning to the development of the argument, it is worth noting that all "arguments from paradox" against the possibility of pastward time travel require a false premise—that every possible form of pastward time travel would let time travelers alter past events. However, a form of time travel which would not allow past-alteration has been understood for decades.

The key to understanding this concept of time travel is the idea that time machines which operate accordingly would not be able to fulfill every time travel request. Author Robert Heinlein may have been the first to suggest what may be referred to as a *gatekeeping mechanism*, a natural process which governs whether any given attempt to travel back to a particular set of coordinates in the past will prove to be successful when a time machine is activated for that purpose.

In terms of pastward time travel via traversable wormholes, for instance, a gatekeeping mechanism would determine, in a given situation of attempted time travel, whether the wormhole manipulation device being used will be able to enlarge the selected natural microscopic wormhole and condition it for transport, or not.*

A gatekeeping mechanism would act to enforce a consistent logic of time travel; any given attempt to send people into the past can only occur in a consistent manner if the past includes their visit as a result of that very attempt. Heinlein imagined that nature would always prevent the success of any other kind of pastward time travel attempt, thereby eliminating any chance of time travel paradoxes. Heinlein revealed this basic but profound insight in a conversation between two characters in his 1964 novel, *Farnham's Freehold*:

> "The way I see it, there are no paradoxes in time travel, there can't be. If we are going to make this time jump, then we already did; that's what happened. And if it doesn't work, then it's be-

*"One can imagine an advanced civilization pulling a wormhole out of the quantum foam and enlarging it to classical size." [17, see p. 1446]

> cause it didn't happen."
> "But it hasn't happened yet. Therefore, you are saying it didn't happen, so it can't happen. That's what I said."
> "No, no! We don't know whether it has already happened or not. If it did, it will. If it didn't, it won't." [20]

It turns out that pastward time travel, while difficult to accomplish, is basic from a logical point of view. Tenses and perceptions of time confuse many issues that are easy to understand within a tenseless picture of space and time. This kind of picture was developed by the German mathematician Hermann Minkowski, and it is the subject of his groundbreaking 1908 lecture, "Raum und Zeit" [21]. Although the term 'spacetime' will be avoided here, other terms associated with the work of Minkowski and Einstein will be used which efficiently refer to important spatio-temporal concepts that would be meaningful in any theoretical framework.

Four-dimensional spatio-temporal coordinates (x, y, z, t) are sufficient to specify any location in our universe at any time, i.e., any *world-point* [21] defined with respect to some arbitrary origin. So, relations between any two world-points can be discussed in a tenseless fashion, just as one would discuss relations between points plotted on graph paper. For instance, regarding time travel by wormhole, the relation of interest concerns whether two world-points are bridged by a traversable wormhole:

> "If it did, it will," describes two world-points bridged by a traversable wormhole.
> "If it didn't, it won't," describes two world-points not bridged by a traversable wormhole.

The antecedent phrases, "[i]f it did" and "[i]f it didn't," refer to what has happened at the intended pastward destination, and the consequent phrases, "it will" and "it won't," describe the corresponding event of success or failure to initiate pastward time travel that will be discovered once the wormhole manipulation device has been activated for that purpose. Note that world-points which are not bridged by a traversable wormhole cannot somehow change to become bridged; the configuration of world-points is fixed in the tenseless picture.

The argument to show that time travel to arbitrary world-points within a single-timeline model is not possible will follow shortly, but first it is necessary to discuss the ontology of time. As will be established below, the only ontology that could accommodate pastward time travel and future-viewing is *eternalism*, also known as the *block universe concept*.

Within eternalism, every event in a given spatio-temporal manifold exists together with every other event in a coherent, unchanging whole, and all times are ontologically identical. (Multi-timeline forms of eternalism need not enter the discussion, for reasons explained above.) Eternalism will be contrasted with the *growing block universe concept* which holds that, while the past has become fixed, the ever-advancing momentary present is ontologically distinct from the past, and future events have yet to be forged in the advancing now.

The reason eternalism is the only ontology relevant in the context of future-viewing and pastward time travel is that these technologies would allow questions about the ontology of time to be answered empirically, in favor of eternalism. For instance, through wormhole time travel or future-viewing accomplished using wormholes, it would be possible for people stationed in different centuries to conduct a two-way radio conversation through the wormhole throat. Demonstrations of this sort would entirely rule out the growing block universe concept. After all, future-dwellers could not reply to us if the future does not exist and time travelers could not visit and return from a future that is not there.* As such, any argument purporting to reach a conclusion with relevance to time travel and use of a "time viewer" [23, see p. 283] to see into the past or future must be cast within eternalism.

A few more background details are necessary before the final argument against the possibility of time travel paradoxes can be presented. It is important to discuss how change and movement are conceptually accommodated within the tenseless, unchanging picture of eternalism.

When particle movements are graphed, four-dimensional *world-lines* are traced out [21]. All world-lines are complete within eternalism. One can see that collections of particle world-lines may describe any object or body in space enduring through time, including all internal occurrences and all actions (e.g., digestion, typing, walking). Such collections will be referred to as *composite world-lines*.

So, within eternalism, the composite world-lines of human beings are complete from birth to death in every physical and behavioral detail. Since a composite world-line is a record of all change and movement, no world-line can be changed or moved. This applies to all past world-lines in both ontologies, and in either view, no individual may change any aspect of his or her future composite world-line.

Change requires a difference between an initial state and a post-change state. Comparing ontologies, under the growing block universe concept it is not possible for a person to change his or her future composite world-line because it does not exist; in this view, the future is made in the objectively advancing present. Under eternalism, even though a person's future composite world-line exists in its entirety, it exists as the accumulated product of actions taken and processes which occur in that person's perceived advancing present. So, under eternalism, it remains the case that one's future composite world-line is not and cannot be changed. It is fulfilled. Philosopher J.J.C. Smart expressed the distinction between acting in the present to produce the future and the mistaken idea of "changing the future," this way:

*As one would expect, the view known as presentism which holds that only the present exists would also be thoroughly ruled out [22].

> ...[T]he fact that our present actions determine the future would be most misleadingly expressed or described by saying that we can change the future. A man can change his trousers, his club, or his job. Perhaps he may even change the course of world history or the state of scientific thought. But one thing that he cannot change is the future, since whatever he brings about *is* the future, and nothing else is, or ever was. [24]

With this background in place, the promised argument for the impossibility of paradoxes arising from pastward time travel will now be presented: Considering whether paradoxes due to time travel could occur at all requires consideration of a successful instance of pastward time travel. Therefore, begin by positing one such instance. For reasons explained above, this is a posit which requires eternalism. So, in this instance of pastward time travel, the composite world-lines of time travelers are necessarily embedded in "the past" as judged with respect to the date of their journey's origin. This means that the actions of these time travelers during their visit are necessarily part of the historical background leading to the world situation of their journey's origin.

So, paradoxes emerging from pastward time travel would only be possible if the composite world-lines of time travelers embedded in the past could be made to change, move, or disappear. However, world-lines cannot be made to change, move, or disappear. Ultimately, pastward time travel cannot lead to paradoxes due to the unalterable geometry of completed world-lines within eternalism, wherein all world-lines are complete. Within a single timeline model, the unalterable nature of world-lines produces all the effects of a gatekeeping mechanism which include making past-alteration impossible.

This argument will now be extended for sake of thoroughness. One might imagine that some unknown method of time travel which somehow operates according to discontinuous relocation might allow time travelers to visit scenes which did not involve time travelers "the first time around." However, examining the tenseless picture of eternalism shows that this is not the case:

> "If it did, it will," describes two world-points associated by discontinuous relocation.
>
> "If it didn't, it won't," describes two world-points not associated by discontinuous relocation.

In order for a time traveler using a form of time travel based on discontinuous relocation to visit a scene which did not involve time travelers "the first time around," specific conditions must obtain. For a given world-point w to qualify as having been without visits from time travelers, w must not be associated with another world-point by discontinuous relocation and w must not be a world-point visited by time travelers using some form of time travel based on translation.

If one symbolizes "world-point w is associated with another world-point by discontinuous relocation" as Dw, and symbolizes "world-point w is visited by time travelers using some form of time travel based on translation" as Tw, then in order for a given world-point w to qualify as having been without visits from time travelers "the first time around," both $\neg$Dw and $\neg$Tw must obtain. So, even a method of time travel based on discontinuous relocation could not allow time travelers to visit world points that were not visited by time travelers "the first time around," since there can be no world-point w for which the statements Dw and $\neg$Dw are both true.

As continuous and discontinuous means of travel exhaust all possibilities for relocation in any spatio-temporal manifold, it is possible to conclude that, regardless of the way in which pastward time travel might ever be achieved, it could never lead to changes to the past or paradoxes of any sort.

This understanding produces unwavering clarity. No type of vexation ever thought to rule out time travel remains.* All of the imagined logical barriers which would fundamentally block the actualization of time machines and foreknowledge instruments have turned out to be illusory.

With any technology that would allow information to be transferred from later to earlier world-points, *temporal gatekeeping* is key. In other words, in any given effort to travel pastward, time machines will only be able to send travelers to parts of the past that were visited by those very travelers as a result of that very effort to send them pastward, and likewise, any attempt to use a foreknowledge instrument to reveal future events will only be successful if, from the perspective of the future, that attempt to peer into the future had been successful. In both scenarios, the world at the "future end" results from the world at the "past end," and so, in either technological case, the resulting state of affairs is necessarily compatible with all events occurring at the "past end."

Related to these findings, quantum information pioneer, Seth Lloyd, with other scientists, produced four papers in 2010 and 2011 which present a formal model here called the *P-CTC model* [25, 28–30]. In effect, the P-CTC model is a temporal gatekeeping model.

3 Obtaining viewer foreknowledge

The three modes of the RNG experiment produce three different kinds of viewing situations. An understanding of these situations is a necessary prerequisite to deciphering how foreknowledge instruments would operate in real-world settings.

*Along with past-alteration paradoxes, another potential problem has been imagined, the "paradox of auto-generated information" or the "unproved theorem paradox" [1, 25]. The unproved theorem paradox appears in a groundbreaking 1991 paper by physicist David Deutsch [26]. Lloyd et al. address this issue. Their "[u]nproved theorem paradox circuit" affirms the conclusion that meaningful information cannot be auto-generated via *closed timelike curves* (*CTCs*) [25]. (CTCs are trajectories apparent within some solutions of general relativity which would allow an object to meet an earlier version of itself—i.e., to travel pastward.) An objection was raised to their resolution of the unproved theorem paradox [27], but Lloyd et al. showed the basis of the objection to be erroneous [28].

P_R produces what will be described as an *independent viewing situation*. Outcomes which have been foreseen in an independent viewing situation during a given session with a foreknowledge instrument are not contingent in any way upon data received in that session.

On the other hand, P_0 produces a *cooperative viewing situation*, a kind of circumstance wherein data received in viewer foreknowledge of an outcome factors into the details of that outcome or is responsible for its very occurrence.

Within independent viewing situations and cooperative viewing situations, there are no logical barriers to the reception of viewer foreknowledge. As such, they are both classified as non-interference viewing situations. These situations represent two different ways of not using data from the instrument to interfere with the outcome. In P_R-mode runs the data is not involved in the outcome at all, and in P_0-mode runs the data is followed exactly. If independent viewing and cooperative viewing exhaust all modes of non-interference, then an interference viewing situation will arise in every other kind of case, exemplified by what happens in P_1-mode runs.

It is important to determine whether there are any basic limitations which must affect the practice of future-viewing. Are there kinds of outcomes a particular foreknowledge instrument operator will fundamentally be unable to foresee?

Operators who are able to achieve an independent viewing situation with respect to a given event will be able to foresee it, for no logical barriers will be encountered. However, no individual can achieve an independent viewing situation with respect to the events of her own future life, assuming she will retain her memories. This important limitation will be called the *self-implication effect* of viewer foreknowledge; individuals are necessarily implicated in their own futures.

What about cooperative viewing situations? Could a person witness video sequences of her own future actions within a cooperative viewing situation if she later follows what she has seen exactly? Attempting to arrange such a circumstance would overwhelmingly tend to produce an interference viewing situation. However, an individual could receive limited second-hand information regarding some general features of her future. To explain, two new terms are helpful:

> *Viewing interval*: The interval of time elapsed between the reception of viewer foreknowledge pertaining to a set of outcomes and the occurrence of those outcomes.
>
> *Operator pool*: The operator of a foreknowledge instrument, along with any additional witnesses (if any) during the reception of viewer foreknowledge, together with other individuals (if any) who—during the viewing interval—will be apprised of the results or who will be instructed or influenced based on such results (whether or not they have been made aware of the existence of foreknowledge instruments). This term carries another layer of meaning, for 'operator' may also refer to a mathematical function; the combined input-to-output processing carried out by members of an operator pool will result in (or cohere with) the future-viewed outcome.

For instance, a person might be informed that she will still be alive in forty years time. This particular factual detail is chosen because it admits no variation other than its falsification. A person could not be truthfully informed that viewer foreknowledge has revealed she will still be alive in forty years time, only for her to somehow lose her life at an earlier point. Operator pools are formed only when viewer foreknowledge has been received. All effects upon the world that a given operator pool will generate within the associated viewing interval have therefore passed temporal gatekeeping. So, these effects will at least partially produce (or, for independent viewing, have no causal relation with) the outcomes received in viewer foreknowledge. These effects, of course, include everything the earlier members of the pool will tell later members of the pool. For this reason, no member of an operator pool will do, say, or successfully achieve anything that will prevent, or result in any modification to, the outcomes foreseen.

How would independent viewing situations and cooperative viewing situations manifest in real-world settings with human operators and witnesses? Either the occurrence of a set of future events is compatible with being foreseen by particular operators and witnesses during a particular future-viewing session, or not. In the case of compatibility, a given future-viewing attempt can succeed. Without such compatibility, operators and witnesses could not gain viewer foreknowledge about what will occur at the chosen future coordinates during that situation of attempted future-viewing. (However, one person leaving the room might be enough to achieve compatibility; this could occur if the self-implication effect had been the cause of interference.)

It is apparent that the logic of future-viewing is another manifestation of temporal gatekeeping. Future-viewing and pastward time travel cohere within a seamless whole.

4 Handling foreknowledge instrument data

So far, the discussion has focused on the actions of networks of human beings within a viewing interval who have obtained viewer foreknowledge. However, in order to account for all of the relevant factors which may lead to a set of future-viewed outcomes, the influences of reactive technological systems within a viewing interval must also be considered.

The RNG experiment involves two cases where reactive technological systems are interposed between the attempt to obtain viewer foreknowledge of an outcome and the outcome itself. A system must (during the viewing interval) be capable of both receiving viewer foreknowledge data and performing actions which could have bearing upon the associated outcomes, in order for either a cooperative viewing situation or an interference viewing situation to arise as a result of that system's presence or involvement. Due to these requirements, other than systems deliberately arranged in laboratory setups to test future-viewing instruments, AI systems are the only kind of technological systems with any likelihood of becoming interposed in the necessary way.

Systems referred to as AI systems today do not qualify as conscious minds. The dream/nightmare of an artifact with conscious awareness, thankfully, has not been realized. In the context of foreknowledge instruments, however, the topic of whether any interposed technological systems are conscious must be treated as a side issue. This is because information processing does not require a conscious being, as any functioning thermostat will demonstrate.

Why is it important to consider the possibility of interposed AI systems? If current trends continue, information processing systems will eventually have the ability to influence real-world outcomes to a much greater degree than they can today. If information processing systems with sufficiently powerful capabilities become members of operator pools, this could produce cooperative viewing situations with results that differ radically from the results that operator pools composed entirely of humans would produce.

In considering the severity this problematic possibility, it is necessary to realize that once viewer foreknowledge has been received, all of the outcomes detailed will come to pass with certainty. In the case of cooperative viewing, the actions of members of an operator pool bring about or strongly factor into the details of the outcomes originally received.

If AI systems are allowed to acquire future-derived information at any time within a given viewing interval, even years into it, they would be factors in the operator pool all along. In such a case, the combined processing and network-coordinated actions of interposed AI systems could easily dominate the outcomes produced. Leaving the door open for AI systems to join operator pools is therefore a grave risk which must be comprehensively addressed.

There is at least one other reason to keep AI systems out of operator pools: The presence of AI systems in the process of attempted future-viewing could produce interference viewing situations in cases which might otherwise have been independent viewing situations or (entirely human-directed) cooperative viewing situations. So, at best, the presence of interposed information processing systems would disrupt our ability to use foreknowledge instruments effectively.

For these critical and interrelated reasons, every effort should be made to ensure that AI systems will not be able to gain access to viewer foreknowledge data. As well, monitoring procedures should be implemented to make sure that AI systems will not be able to retain data derived from viewer foreknowledge for long enough to utilize it in cases where a breach has occurred.

To prevent AI systems from accessing viewer foreknowledge data to support the enforcement of *AI safety*, such data could be distributed exclusively in encrypted packets which have been flagged as off-limits for decryption by AI systems. Any processing which could constitute decryption of flagged packets by AI systems would be considered forbidden processing. Future AI systems should be designed to contain separate, internal monitoring systems which would be programmed to immediately put the monitored AI to sleep if an instance of forbidden processing is detected.

Along with data access control, memory control is another important protective strategy. Memory control may be the most fundamental way to keep all of the potentially negative effects of an "intelligence explosion" [31] at bay. Future AI systems should be designed to sleep several times a day (others could cover for the ones that are asleep). This way, memory contents could be optimized and routinely cleared of all potentially hazardous data structures. Regular memory clearing and the addition of internal monitoring systems should be seen as necessities for AIs, much like the use of safety glass for car windows is recognized as necessary.

From these considerations it is apparent that it is possible, in principle, to fundamentally prevent any of the potentially negative effects of an intelligence explosion. One of the most important aspects of AI safety, in a world with foreknowledge instruments, would be preventing AIs from acquiring and retaining viewer foreknowledge data. Successfully navigating the rise of artificial intelligence will be difficult enough without letting AIs dominate operator pools.

Additional ideas related to the topic of AI safety will have to be saved for another work. It will be noted, however, that if artificial systems are ever constructed which would qualify as conscious beings—artificial systems fundamentally unlike any type of system ever built or currently considered—an entirely different approach would be required due to the ethical concerns which would apply only in that case.

Of course, ethical concerns can only apply to conscious beings because only conscious beings are able to suffer. So, these same ethical concerns demand that AI systems should always be designed so there is absolutely no chance of producing a conscious being. It would be horribly inhumane to cross this line—to do so would be just as wrong as the creation of human-animal hybrids, for largely the same reasons.

There is no basis for feigning confusion about whether any current AI systems qualify as conscious beings. There are a lot of philosophical positions out there, but no one believes that there is even a remote chance that the line has been crossed, or has even been approached. No matter how fast and capable of solving problems AI systems ever become, let them remain, as they are today, non-conscious information processing engines, systems which cannot suffer or desire.

5 Assurance protocols

Foreknowledge instruments will be put to practical use if and when they become available, but how could they be utilized? Foreknowledge instruments could be combined with current computer technology to allow us to comprehensively manage outcomes in a wide variety of circumstances. For instance, with the right systems and protocols in place, it would be possible to entirely eliminate flight accidents and other threats to air travel safety.

Here is an outline of one way this might be done: All aircraft operating systems could be modified so that, after landing, the higher engine speeds required for take-off are locked out by default. In order to fly again, it would be necessary to obtain an encryption code, here called a *confirmation key*, to unlock these higher engine speeds.

Each flight plan would be assigned a unique confirmation key during the planning stage. For a given flight plan to be allowed to progress to the point of becoming a scheduled flight, the assigned confirmation key would have to be retrieved from a future-based assurance database. Data could be retrieved from a future-based database by means of a wireless data exchange conducted between *intertemporal data nodes*, devices based on foreknowledge instrument technology.*

Here is the critical detail: By procedural design, deposit of a given flight's confirmation key, for earlier retrieval, may only be initiated after that flight has safely landed. As long as this rule is not violated, database integrity is maintained, and plane operating systems are not compromised, all flights which take off under this assurance protocol will land safely.

The steps of this protocol would have to be followed in a particular order. Once a confirmation key for a given flight plan has been generated, if it is not subsequently found in the future-based assurance database (by looking ahead), that flight plan would have to be canceled. Then, another set of parameters constituting a new flight plan (such as the aircraft and pilots to be used, time of departure, and so on) would be prepared and another confirmation key would be generated. This process would continue until a newly generated confirmation key has been found in the future-based assurance database.

Why (one might wonder) is the particular order just described important in this protocol design? In other words, why not simply begin by querying the future-based database, far enough ahead, to find out which flights will land safely, and only schedule those flights? The answer is that such an ordering could not work. Flight plan specifics and associated confirmation keys must have an origin. Since auto-generated information is not possible, no practical system could be based on the expectation of its reception.

*Two varieties of intertemporal data nodes may be described as follows: A *passive node* would consist of a Faraday cage of known spatial coordinates containing a wireless data communication device wired to the Internet of its time period. An *initiating node* or *active node* would consist of a Faraday cage of known spatial coordinates containing a wireless data communication device wired to the Internet of its time period, coupled with a temporal instrument (such as a foreknowledge instrument) which is able to establish light-path continuity with node interiors in other time periods. Initiating nodes would allow spontaneous wireless data exchanges to be conducted between different time periods.

Assurance protocols could be extended into several other domains. So many of our current problems are based on the seeming necessity of facing an entirely unknowable future.

6 Intertemporal networking

Another application of foreknowledge instrument technology is *intertemporal networking*. An intertemporal Internet could be founded by connecting active intertemporal data nodes to our current Internet. Foreknowledge instruments are the only components of active intertemporal data nodes which remain unavailable. Once foreknowledge instruments are invented and/or made available, if they really are part of our future, then achieving access to a future intertemporal Internet will likely be among the major milestones to follow.

The development of an intertemporal Internet is a natural aspect of societal future-sightedness. When one considers widespread access to time viewers, obvious privacy and intelligence concerns arise. To address these issues, it would be necessary for foreknowledge instruments and other kinds of time viewers, such as past-viewing instruments, to be made exclusively accessible over the (standard) Internet; then, the servers which govern time viewing could be programmed to respect a database of spatio-temporal coordinate limitations in order to prevent rampant voyeurism and espionage. In this way, the four-dimensional coordinate volumes within which private residences, businesses, and government buildings are contained could be comprehensively protected against time viewer access.

For this kind of solution to function, each time period within an *intertemporal society* must have the ability to contribute to the management of such a database. (An intertemporal society is an enduring population which benefits from intertemporal coordination among its time periods.) To enable shared management of a coordinate limitation database within an intertemporal society, shared access to an intertemporal Internet among its time periods would be required.

While foreknowledge instruments and related technologies could provide direct observation of past or future scenes, many people would primarily use these devices in the form of active intertemporal data nodes to access the intertemporal Internet. In recent years, people have become accustomed to receiving most of their news electronically; with access to an intertemporal Internet—unless an interference viewing situation is encountered instead—individuals could discover what will happen decades or even centuries ahead of time. Reading about future history would be similar to reading about past history, though one would have to be careful with such information in order to successfully obtain it in the first place. An intertemporal Internet could also be used purely for entertainment purposes. Would it not be endlessly fascinating to hear the music of the far future?

These possibilities may seem outlandish until it is recognized that members of an intertemporal society would live in an intertemporal world, a kind of situation that would be very different from our current situation. All happenings in an intertemporal world would be constrained according to the inviolable barriers of temporal gatekeeping and the self-implication effect, thus ensuring that information flows would operate coherently, without ever even a hint of paradox.

As a case in point, it might be thought that the prospect of people having access to future news would be inherently threatening to the coherence of future events: For instance, might an article from the future revealing an invention not yet invented give someone else the opportunity to "invent" that technology instead, thereby leading to changes to the future? Or worse, could an invention emerge purely from an auto-generated information loop? Of course, neither of these scenarios reside within the realm of possibility. As raised above, the P-CTC model explains why auto-generated information cannot emerge from time travel or future-viewing. Temporal gatekeeping, also addressed by the P-CTC model, explains why the future and the past are safe from changes.

Anyone who is able to acquire future-derived information will, by virtue of having been able to acquire it, not use that information to change the future. This is true even though no mysterious force prevents a person from misusing future-derived information once it has been acquired. Whoever has acquired future-derived information is in an operator pool, so no individual can both acquire future-derived information and use it to change the future.

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