Time Travel: Some Science of Fiction

By John Michael Williams

2010-07-09

The fiction of time-travel usually makes it paradoxical and therefore impossible beyond physics.   A few physical postulates, however, can make time-travel merely impossible physically.

Introduction

A few months ago, my home suffered an electrical power outage which lasted two days. The result was no heat, no electricity, and no hot water -- back to the nineteenth century! Rather than go to work unshaven and possibly smelly, I decided to stay home. I spent the time lying around, dozing, listening to a battery-powered radio, and reading by candle light.

After a while, I began to think about time-travel -- how impossible it would be, physically, because of violations of energy and momentum conservation, and because of violation of the Second Law of thermodynamics.

Regardless, I did work out what I think are minimally impossible principles of time-travel; and, this is what I am presenting here.

Time-Travel is Memory Inspired

First, how does the idea of "travel" in time arise? From a physical perspective, it does imply a certain interchangeability of coordinates in time with those in space. This is reminiscent of Einstein's resolution [1] of the mysterious but physically verified universal constancy of c, the speed of light.

But, more intuitively, time-travel is suggested simply by the existence of human memories and of books recording a history of past events.

We all can recall events in our lives which can be visualized, or heard again, from memory. This possibility of reliving past events leads easily to the idea of redoing those events -- returning to the past to reexperience happy moments or to correct what we now might consider past mistakes.

Likewise, when we read a book depicting a chronology in the past, we can page forward and backward in time, in effect recollecting and reexperiencing events which occurred before we were born.

It's not a big step from this to being able to move, not just from page to page, but from event to event in our memories -- and thence to imagine being able to move from event to event in time.

Time-Travel can be Science Fiction

From idle imaginings of travel in time, it is not difficult to write a book about such travels. The best of such books are not just fantasy, but are science fiction.

What does this mean? What is ***science fiction***? The usual definition is that it is fiction which is based on science, which presents definite scientific ideas or technological developments, and then develops a story consistent with that science. For example, a story about exploration of the Moon or Mars might be based on rocket science and related technology. It would not permit the sudden appearance of Moon Fairies which were inconsistent with the story's scientific assumptions. However, if some scientific justification of Moon Fairies was presented (*e. g.,* biological entities arising from alien spores, inert if undisturbed), then science-fiction, as opposed to a hodge-podge of fantasy, could be justified.

The first prominent work of science fiction depicting time-travel was H. G. Wells' *The Time Machine*, which related an adventure including travel to the future. As it happens, Wells was an historian. A Warner Brothers movie was made from this book in 2002; the movie depicted travel to the past and the future -- and a villain of the future of this movie pointed out the paradox described herein.

Science fiction on time-travel has become popular in modern motion pictures. To name a few, these movies include *The Terminator*, *Time Cop*, *The Returner*, *Retroactive*, *Frequency*, *Deja Vu*, and *Twelve Monkeys*. All these stories provide only for travel to the past, sometimes with an option to return to the "present" epoch in which the travel was initiated. *Frequency* is a bit unique in that it involves only two-way radio communication between the present and the past, not travel *per se*. The science in *Frequency* is based on string theory. The science in *Retroactive* is based on a high-energy physics facility (the abandoned Texas SCC) but otherwise is unspecified. The other films use scientific props and story rules to limit the fantasy and keep it consistent, even if physically impossible.

The long-running *Dr. Who* television series featured a closet time-traveller who could visit the future as well as the past.

The time paradox. The stories just named gloss over the paradoxical side of their assumptions. Generally, they assume that a change in the past mediated by the traveller would have the effect of "updating" conditions in the epoch in which the travel was initiated.

In *The Terminator*, for example, an assassin is sent back in time to kill the mother-to-be of a military leader, thus preventing the leader ever from existing. The paradox here is just that, if the leader never existed, then neither would there be any reason to send back an assassin; therefore, with no assassin, the leader would exist, *etc*. The leader requires the assassin, who requires the leader to exist, and the assassin causes the leader not to exist. This quandary can be seen to exemplify the self-reflexiveness of the part-in-the-whole required for a true paradox by the Whitehead and Russell formal definition [2].

Now, a paradox may be overlooked in a work of fiction, allowing the story to proceed in an amusing and even spell-binding way; but, we can not accept the science if we permit the paradox.

Therefore, I am proposing here a physical resolution of the paradox of time-travel which, regardless, still implies the inherently unphysical violation of conservation laws mentioned above. I develop this resolution postulate-by-postulate as follows:

I. Time-Travel is Confined to a Specific Volume

The time machine to be defined here will transport a certain, fixed volume of space, and anything in it, to some chosen time in the past.

For example, our time machine might cause displacement in time of everything within a specifically localized sphere of radius one meter. Everything in this volume is transported in time, and nothing else.

Much of relativity theory is based on an inertial ***reference frame*** associated with displacements in space around any object which can be accelerated. By analogy, our time machine will associate a ***reference volume*** of space enclosing every object to be displaced in time.

II. Time-Travel is Confined to Travel into the Past

We don't need fictitious, unphysical machinery to travel to the future (with no return). We already have the machinery for this, at least in principle: Special relativity permits us to accelerate an object to a speed close to that of light; this causes time (proper time t_p) to pass more slowly for the accelerated object than for the rest of the universe. The rate of proper time is given by the familiar ratio, $t_p = t/\gamma$, in which γ is the total energy E of the accelerated object divided by its rest energy mc^2. When the object is decelerated and returned near its original spatial location, it will return to a time farther in the future than passed for it during its journey.

So, our time machine need only be built to transport objects to the past and, optionally, to return those objects to the epoch during which the transportation was initiated.

III. Time-Travel to Locations in the Past is Feasible

Postulate I above implies the existence of a problem ignored in all the works of fiction named above: This problem is that unavoidable motions at the point of departure create ambiguity of spatial location at the destination and thereby prevent meaningful functioning of the time machine.

To understand this ambiguity, it is only necessary to understand that the Earth is not an immobile place at the center of the universe. To quantify the problem, assume that when the time machine is activated, our reference volume is displaced just one second into the past:

The Earth rotates about its axis at about 1200 km/hr at a typical, intermediate latitude, and this implies a lateral speed of movement of the Earth's surface of about 300 m/s, roughly the speed of sound in air.

Therefore, if we take the center of the Earth as a positional reference for our time travel, our reference volume will arrive in the past at a point about 300 m to the west of where it started, assuming that we are at a middle latitude.

But, why should the center of the Earth matter? The Earth is revolving around the Sun at about 30 km/s. Using the Sun as a reference point for the one-second excursion, our reference volume might end up 30 km to the west, in the Earth's lower crust at a temperature of 2,000 C, or in low Earth orbit, in an equally deadly vacuum -- or anywhere else, as much as 30 km away. The exact location in the past would depend on the longitude and on the departure time of day. Also, what would be the momentum of an object in the reference volume? Should the momentum be changed because of the spatial displacement?

It's not hard to see where this ambiguity leads us: We have the Sun's motion among the nearby stars, the solar system's revolution around the center of our galaxy, and the flight of galaxies from one another in the expanding universe. Time-travel to a specific location would appear to be an example of totally unpredictable chaos!

So,we must assume that travel in time at a specific location on the Earth's surface, unless to a differentially short time in the past, is made possible because the time machine somehow can calculate and impose a spatial displacement cancelling all the enormous and ambiguous astronomical movements separating the visited past from the departed present.

We shall assume here that this can be done by our machine: Our machine will reach its final displacement in time by integrating an infinite set of differentially small time displacements and somehow automatically cancelling, respectively, all associated spatial displacements relative to nearby objects.

Wormhole Elaboration

The location problem applies equally to "wormhole" or other extra-dimension formulations (*e. g.*, S. Hawking [3]). We can tease apart the present (departure) epoch from the past (destination) epoch by means of a "wormhole" theory. To do this, we start by assigning different time coordinates, present and past, to the same spatial location, thus describing the familiar lapse of time. We shall not discuss here the idea of a wormhole as a way to travel in space.

Wormhole time-travel is based on the idea that the 4-dimensional space-time of relativity could be "bent" in some higher-order space and thus folded back on itself so that, in the higher-order space, the interval between otherwise remote points might become negligible. Thus, by folding space, one might bring into close proximity points which have about the same space coordinates but very different time coordinates. If one then could travel a short distance in the higher-dimensional space, one effectively could travel back (and forth) in time. Travel through the wormhole.

Unfortunately, the lack of an absolute coordinate grid for physical space-time makes this idea impractical: Yes, in the rest frame of the time machine in the present epoch, both the present instant and the chosen past instant would have well-defined locations and intervals. The wormhole geometry could be well-defined -- for an instant.

But, relativity theory, many times over confirmed as correct, demands that locations and intervals in space-time, and thus in any higher-order space, not permit of the possibility of an absolute space-time grid with a physical extent in space-time.

Thus, the ***non***inertial rotation of the Earth, its orbiting about the Sun, the various astronomical motions mentioned previously, all cause an undefined spatial drift, actually a tangle, in time of the two ends of the wormhole in the hypothesized higher-order space. This means that no obvious physical connection, based on the geometry or on the unaided forces of nature, can be maintained. Wormhole fiction writers usually do not account for relativity theory, with which they are inconsistent -- somewhat the way that space-travel fiction often has travellers walking around on the floor although in gravitationless deep space.

A humanly-designed, adaptive mechanism must be postulated as part of the time machine to maintain the space-time interval between wormhole endpoints. As before, we here overcome this problem by postulating that the time machine can integrate differentially small spatial displacements and cancel them in time to maintain a meaningful transition from the present location to a well-defined location in the past.

IV. A Return is Required and Instantaneous

Assuming Postulate III, we still have a different problem: Yes, we know that we are violating conservation laws by going back in time; but, what happens in the surrounding, unviolated environment?

Let us assume that the reference volume takes the shape of a sphere, and that the reference-volume displacement proceeds as follows: On departure, the volume shrinks quickly to a point; on arrival in the past, it grows quickly from a point. The animations in *The Terminator* and its sequels imply such a process.

Under these assumptions, in the departure epoch, if the sphere very suddenly should disappear into the past. the air around it would rush in suddenly, causing a destructive implosion. Likewise, to whenever the sphere was displaced in time, it should cause an even more forceful explosion.

As an alternative to explosion, we might suppose that the sphere, newly appearing in the past, superposed itself on the preexisting air or other matter: Such a process would weaken or disrupt any object contained in the reference volume, at least by filling it with foreign material such as air (between the molecules?). This alternative (touched upon in a movie, *Timeline*) will be ignored in the rest of this discussion, because it implies too much destruction and disorder of objects or persons within the reference volume -- not to mention the destruction and disorder at the destination location. We shall assume the implosion/explosion process modified as follows:

The past problem. The arrival-explosion problem in the past seems unavoidable, but we can moderate it by making the arrival in the past somewhat gradual; we can assume that a departure from the past also will be somewhat gradual, reducing the implosion there (then).

The present problem. In the departure ("present") epoch, we can avoid most of this problem by requiring that the time machine always return the reference volume to the departure epoch, at the departure location, after a differentially short time as measured in the departure epoch. Thus, we superpose, in a moderately brief time, the departing and returning volumes, which are the same reference volume. Any implosion or explosion thus will be moderated greatly, depending on the specific sizes of objects which may have been transported back or forth through time.

V. Time-Travel Without Paradox

Now that we have put to rest, at least provisionally, the simpler problems of sending someone or something back in time, we should try to prevent paradox from compromising our approach. We can do this by applying the same rationale as is used in special relativity.

The twin paradox. In special relativity, there once was a problem called the "twin paradox"; it went like this: Suppose we have two identical-twin brothers or sisters. We accelerate one of them and then return them together after some time. According to special relativity, the accelerated twin now will be younger than the other one. But, the supposed paradox goes, the relative motion of the two twins can be interpreted in the rest frame of the accelerated twin; thus, the unaccelerated twin has been accelerated away and back and therefore should be the younger. They can not both be younger; whence, the "paradox". Notice the self-reflexiveness: Each twin is entirely defined by the reference frame of the other.

This apparent paradox simply is a failure to understand relativity. The unaccelerated twin could be the younger only if the first twin never had been accelerated, and if the unaccelerated twin had been accelerated along with the entire rest of the universe! The paradox arises only because the reader confuses the whole universe with a single twin. The unaccelerated twin was not accelerated relative to the rest of the universe, so time lapsed for the latter twin at the same rate as it did for the rest of the universe. Acceleration in any rest frame causes time dilation only for the object accelerated. Another way to see this is to recall that the value of γ for time-dilation depends on energy E, and only the accelerated twin gained any energy.

The time paradox. The resolution of the (false) twin paradox can be applied to the time-travel paradox described at the beginning of this discussion. Applying the above argument to time-travel, we simply recognize that events befalling the time traveller are real but do not affect events in the period preceding the departure of the time-traveller into the past. The rest of the universe did not do any time-travelling, so time-travel had no effect on it.

There is no need for postulating "multiverses" of alternative universes, created by changes in the past during time-travel. When a reference volume is transported to the past, the experiences of persons so transported are in reference to the travel: They can experience the past, modify it by their activities, and return. After their return, they find that the past outside the reference volume has not changed at all, only their own experiences have changed. Upon return, the effect of these experiences, limited by the reference volume, is transported back with them, to the epoch in which they departed.

All effects of the travel, upon return to the present, are lost, except those within the reference volume: The "modified" past is no more real than the past of the real universe in the absence of time travel. So, multiple travels to, and returns from, the same past time always return to the same past conditions. Someone, or something, left in the past by the traveller is annihilated upon return of the reference volume and existed only for the differentially short instant that the reference volume was "gone" from the present epoch.

One might try to view the past visited and modified by travel as analogous to the matter in a black hole -- inaccessible, but still existing. However, this analogy would be very inaccurate, because a black hole interacts gravitationally with the rest of the universe; the past visited and modified by our time machine never can be revisited and interacts with nothing, because it never existed.

This implies, in particular, that a returning time-traveller suddenly could become older after a prolonged trip into the past. But, there is no way a returning traveller could return younger.

The resolution of the idea of time travel which is presented here is completely self-consistent logically, entails no self-reflexiveness, and therefore implies no possible paradox.

We now explore a couple of examples of the application of this resolution to clarify how it might work -- always keeping in mind its physical impossibility because of conservation law violations:

Example 1. Suicide by Annihilation

Suppose a fellow becomes depressed and wishes to commit suicide, but without getting hurt. He steps into his time machine and goes back 50 years to kill his grandfather before his father was conceived. He expects that he then will cease to exist, thus ending his miserable life painlessly.

Let's look at this process graphically, but in view of our previous postulates. In the diagram in Figure 1, the passage of time in the rest of the world (nontravelling universe) is shown on the vertical axis, and the lapse of time for the time-traveller during the excursion into the past is shown on the horizontal axis. Relativistically undilated time that lapses for both is drawn increasing to the right at 45°:

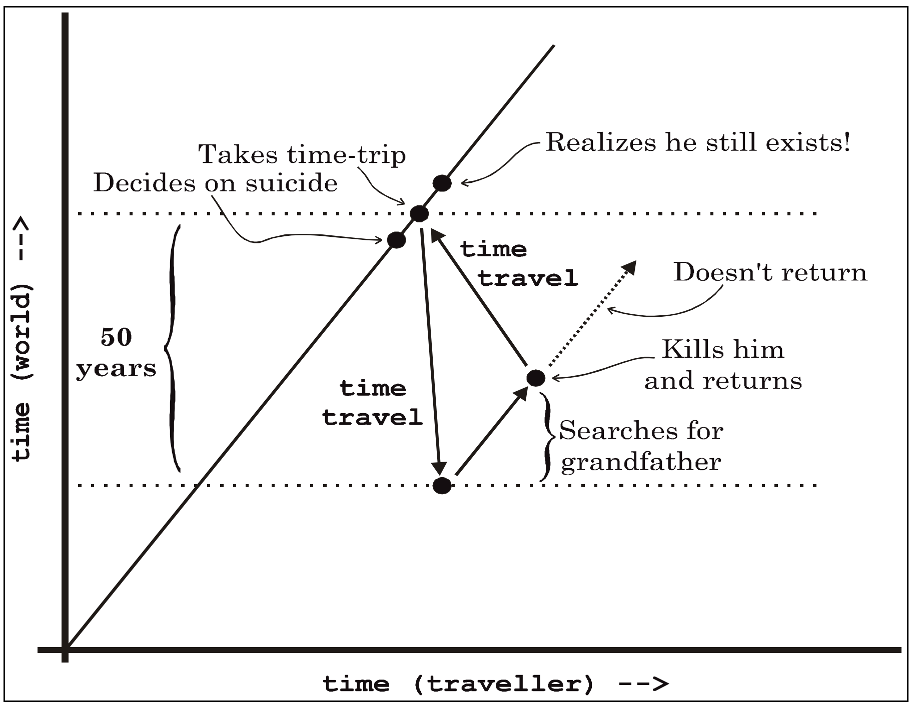

Fig.1. Resolution of a time-travel paradox. Durations not to scale. After the traveller has killed his grandfather, he may return immediately or remain in the past for some time. The alternative, labelled "Doesn't return", is allowed if the reference volume returns without the traveller.

To prevent a paradox, the death of the grandfather physically must be real to the traveller, but it must not have any ***other*** effect on the world to which the traveller returns. Like a memory or the writings in a history book, the death of the grandfather has no physical effect on the world (unless, of course, the corpse is brought back with the traveller).

Bizarrely but not paradoxically, the traveller may choose not to return immediately; in that case, in this example, he has killed someone unnecessary to his continued existence, and he might, of course, be arrested and prosecuted for it -- in a past unconnected with the epoch from which he travelled. When the time machine returns the reference volume to the departure epoch, the departing traveller may not be in it and, if not, effectively has been annihilated by that return.

So, we have just one argument against time-travel: Violation of conservation laws.

Example 2. Burglary Without Criminality

In this example, we apply the preceding analysis to another task which does not entail a paradox:

Our traveller, a burglar by occupation, arms herself with advanced tools and goes back in time to 1975, where she breaks into a bank vault and steals the Hope diamond; she then returns with it.

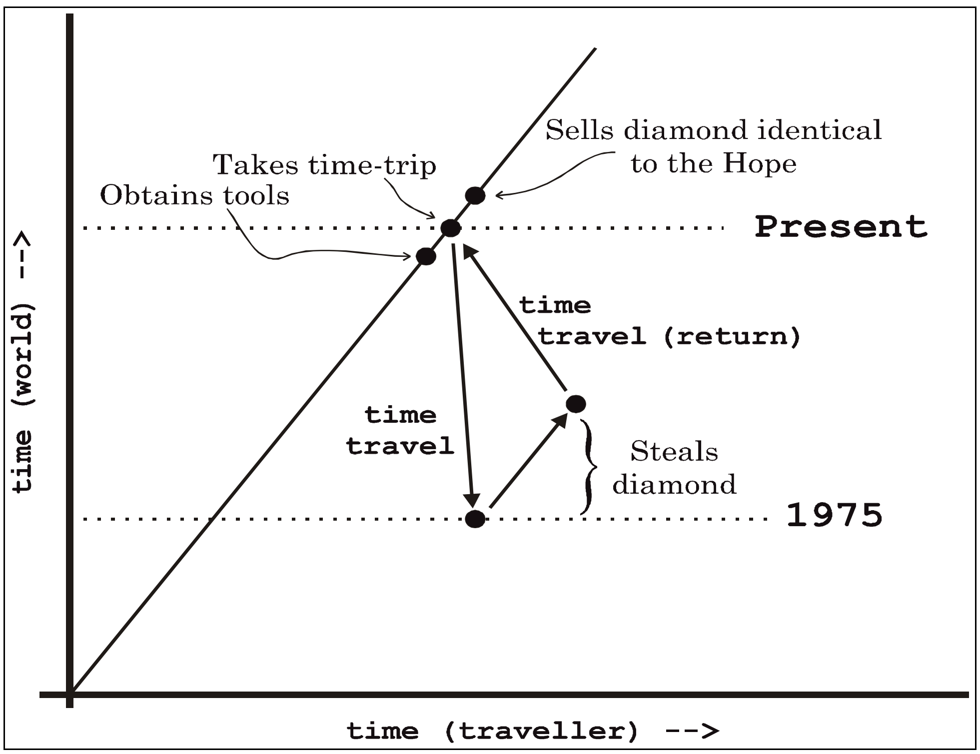

Fig. 2. Time-travel for the perfect crime. A burglar duplicates the Hope diamond by stealing it only in the past.

The result is that there now would be two almost-identical Hope diamonds, because the theft could have no effect on the Hope diamond, but the return from the past carried the Hope diamond with it, in the reference volume. The only difference would be that the stolen Hope diamond was some years "newer" than the original one. We see an obvious violation of conservation laws, but there is no paradox.

In either of the examples above, our traveller would have returned a little older (and hopefully wiser) than when he or she left, depending on how much time was spent in the past.

Example 3. Perpetual Motion (or, the Salt Mill in the Sea)

In this last, trivial example, conservation laws and the laws of thermodynamics are violated on purpose.

Our time-traveller owns a petroleum refinery and lowers the time machine into a small storage tank filled with high-octane gasoline. The reference volume encloses a stainless-steel sphere slightly less than one meter in radius; the sphere in turn is connected to a hose, a vent pipe to admit air, and a suction pump.

The time machine is programmed to return one second into the past, repeatedly. Upon completion of each excursion, the reference volume is pumped dry, the gasoline is moved to another storage tank, and the time machine repeats the same excursion.

With an investment of a few barrels of high-quality fuel, the refinery thus produces an inexhaustible supply of gasoline. The same process could be repeated with highly enriched uranium for a power plant.

V. Summary

I have tried to present a set of informal postulates describing a variety of "time travel" which requires minimal violation of physics and rationality. I did this in part by using an analogy to the conceptual framework of special relativity. The approach here perhaps someday might be improved to make it more physical, but that is an accomplishment which must be left to the past.

References

[1] A. Einstein. On the Electrodynamics of Moving Bodies. *Annalen der Physik*, 1905. Translated into English in *The Principle of Relativity*, New York: Dover, 1952.

[2] A. N. Whitehead and B. Russell. *Principia Mathematica* (2nd ed.), Vol. I, Section II.VIII ("The Contradictions"). London: Cambridge University Press, 1963.

[3] S. Hawking. How to build a time machine. *Daily Mail,* 2010; online at: `http://www.dailymail.co.uk/home/moslive/article1269288/STEPHENHAWKINGHow-buildtimemachine.html`.