Relative Simultaneity Does Not Exist

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Abstract: Relative simultaneity predicted by special relativity is shown to be false. The well-known train-embankment thought experiment fails to demonstrate the phenomenon and global simultaneity as exists in the GPS invalidates the prediction.

Keywords: Relative simultaneity, time dilation, Lorentz transformations, Selleri transformations, Earth-centered inertial (ECI) frame, GPS.

1. Introduction

Relative simultaneity is a concept introduced by the special theory of relativity [1, 2]. It specifies that spatially separated events which are simultaneous in one inertial frame are generally not simultaneous in any other inertial frame. While this is widely illustrated in the literature using the well-known train-embankment "thought experiment", it is one of those aspects of special relativity that has never been experimentally tested. Lack of experimental confirmation is surprisingly also the case for the foundational light speed invariance postulate of special relativity, though in this case there have been numerous attempts over more than 100 years [3]. Unfortunately, this postulate turns out to be untrue as it is now known that light travels faster West than East on the surface of the Earth. This fact has been established using the synchronized clocks of the Global Positioning System (GPS) [4-9]. It is precisely for this reason that clocks fixed on the surface of the Earth cannot be synchronized when light speed c is assumed, necessitating the introduction of the so-called "Sagnac correction" if synchronization is to be achieved [10].

In view of the invalidity of the light speed postulate, it is not surprising that several unresolved inconsistencies in the theory have been identified including those by Selleri [11], Phipps [12] and Gift [13]. In keeping with this trend, Engelhardt [14] recently identified another inconsistency in which time on synchronized clocks in one inertial frame when transformed to another inertial frame using the Lorentz transformations does not coincide with time on

synchronized clocks in the other frame. In this paper on the basis of this observation by Engelhardt, we examine the closely related issue of relative simultaneity and show that this untested phenomenon is non-existent.

2. Relative Simultaneity in Special Relativity

In his inaugural paper [1, p40], Einstein discussed the notion of simultaneous events. In laying the foundation for defining simultaneity, he considered an "A time" and a "B time" for clocks at two spatially separated points A and B in an inertial frame. Towards "a common "time" for A and B", under the assumption of constant light speed for a light ray travelling from A to B and reflected back to A, he defined clocks at A and B to be synchronized if

$$t_B - t_A = t'_A - t_B \tag{1}$$

where t_A is the "A time" or time at clock A when the light leaves A, t_B is the "B time" or time at clock B when the light ray is reflected at B and t'_A is the "A time" or time at clock A when the light arrives back at A. Following this he stated "The "time" of an event is that which is given simultaneously with the event by a stationary clock located at the place of the event, this clock being synchronous, and indeed synchronous for all time determinations, with a specified stationary clock." It follows therefore that since the theory holds that light speed is *c* in all inertial frames, then all clocks in any inertial frame can be synchronized such that simultaneity can be established in that frame using these clocks. In support of this, Katz points out [15, p31] "In any inertial frame the clocks of all observers are synchronized. … In any one frame there is no doubt as to when two events are simultaneous, whenever they occur. If two events occur at the same time, the same reading of the clocks located at the places where the events occurred assures us that the events were simultaneous."

Now let there be an inertial system S with coordinates x, y, z, t in which the speed of light is *c*, and another inertial system S' having coordinates x', y', z', t' which is moving at velocity *v* relative to S along the x axis, the two systems S and S' being coincident at $t = t' = 0$. Then the Lorentz transformations which relate coordinates in the two frames are given by [1-3]

$$x' = \gamma(x - vt), \quad y' = y, \quad z' = z \tag{2a}$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \tag{2b}$$

where $\gamma = 1/\sqrt{1-\beta^2}$ and $\beta = v/c$. Consider an event 1 at (x_1, t_1) and an event 2 at (x_2, t_2) which are simultaneous in S i.e. $t_1 = t_2$ with times determined using synchronized clocks C_1 and C_2 which are stationary in S as shown in Fig. 1. Then using equation (2b), the corresponding times in S' are given by

$$t_1' = \gamma(t_1 - \frac{vx_1}{c^2}) \tag{3}$$

$$t_2' = \gamma(t_2 - \frac{vx_2}{c^2}) \tag{4}$$

where t_1' and t_2' are registered on clocks C_1' stationary in S' at a position coinciding with x_1 and C_2' stationary in S' at a position coinciding with x_2. Since $\Delta t = t_2 - t_1 = 0$, the time interval $\Delta t' = t_2' - t_1'$ in S' between these two events is given by

$$\Delta t' = \gamma(t_2 - \frac{vx_2}{c^2}) - \gamma(t_1 - \frac{vx_1}{c^2}) = \gamma(x_1 - x_2)\frac{v}{c^2} \neq 0 \ , \ x_1 \neq x_2 \tag{5}$$

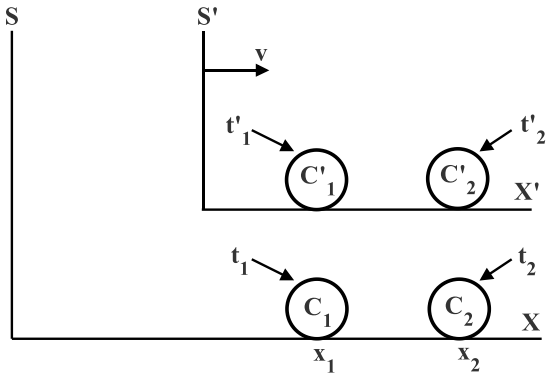

Fig.1 Synchronized clocks C_1 and C_2 in S and C_1' and C_2' in S'

It follows from the theory that spatially separated events that are simultaneous in S corresponding to $\Delta t = t_2 - t_1 = 0$ are not simultaneous in S' since from (5), $\Delta t' = t_2' - t_1' \neq 0$. This is relative simultaneity as predicted by the theory. However, the clocks in S' are also synchronized since light speed there is c and therefore a "common time" is available. Hence, just as $t_1 = t_2$ corresponding to simultaneity can be established in S because clocks C_1 and C_2 are synchronized, simultaneity in S' can also be established using synchronized clocks C_1' and C_2' corresponding to $t_1' = t_2'$. Thus, at the instant $t_1 = t_2$ on clocks C_1 and C_2, the spatially coincident clocks C_1' and C_2' in S' which carry the same time $t_1' = t_2'$ give

$$\Delta t' = t'_2 - t'_1 = 0 \qquad (6)$$

i.e. the simultaneous events in S are also simultaneous in S'. This is absolute simultaneity that follows from considerations within the theory. The theory therefore gives two different and contradictory results (5) and (6) for $\Delta t'$ and is therefore inconsistent.

What the scientific community did was to embrace the prediction $\Delta t' \neq 0$ which is relative simultaneity and ignore the synchronized clocks in S' which indicate $\Delta t' = 0$ i.e. absolute simultaneity. The result $\Delta t' \neq 0$ should have been seen as a clear indication that the theory is flawed since $\Delta t' \neq 0$ suggests time for one observer in S' being ahead of time for the other spatially separated observer in S' even though a "common time" is available on the synchronized clocks in S' which register $\Delta t' = 0$.

3. Experimental Test of Relative Simultaneity

As indicated earlier, relative simultaneity has never been experimentally tested. In this section we discuss a thought experiment widely used to demonstrate relative simultaneity and an actual experiment using the GPS that tests the predicted phenomenon.

3.1 Train-embankment Thought Experiment

Einstein [16] and most authors use the well-known train-embankment thought experiment shown in Fig. 2 in order to demonstrate relative simultaneity. Thus, a train AB travels along a

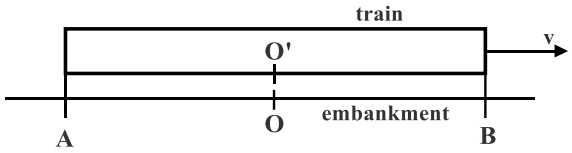

Fig. 2 Train-Embankment Thought Experiment

railway at uniform speed v in the direction B alongside an embankment. Let there be an observer O' on the train positioned at the middle of the train and an observer O coincident with O' on the adjacent embankment. At this instant let two strokes of lightning occur simultaneously at A and B with respect to observer O which means rays of light emitted at A and B where the lightning occurs meet at observer O on the embankment. For the observer in the middle of the train, two rays of light emitted by the flashes of lightning travel towards the train observer O'. Since O' is moving towards the light coming from B while moving away from the light coming from A, according to Einstein [16, p25-26] "the observer will see the beam of light emitted from

B earlier than he will see that emitted from A." He concludes "Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash B took place earlier than the lightning flash A."

This demonstration suffers from a serious flaw. Since the train is moving at constant speed, it constitutes an inertial frame and therefore according to the light speed invariance postulate, light speed within the train is constant in all directions. Therefore the two light beams that move toward observer O' travel at the same speed within the frame of the train and since they travel the same distance will meet at observer O' in the train just as they did with the observer O on the embankment. It follows that the observer on the train, according to the theory, perceives the lightning strikes to be simultaneous just as the observer on the embankment. This contradicts relative simultaneity described above in the thought experiment by Einstein and used by almost every textbook writer on the subject to demonstrate the phenomenon.

This problem for the thought experiment posed by the light speed invariance postulate has been recognized by Jammer [17, p169] who suggested on this basis that "simultaneity is not a relativistic concept". Nelson [18] also considered the issue and argues on similar grounds that the thought experiment cannot be used to prove relative simultaneity even though he does not question the validity of the prediction. Thus, the train-embankment thought experiment fails to demonstrate relativity of simultaneity predicted in (5) and it is therefore difficult to understand why this obviously flawed demonstration has been accepted for over 100 years!

3.2 Experimental Test Using the GPS

It is now possible to test the reality of relative simultaneity. This is done using available technology in the form of the GPS. This is a modern navigation system that employs a set of accurate synchronized atomic clocks in its operation [10]. Based on the IS-GPS-705 Interface Specification [19], GPS signals propagate in straight lines at the constant speed *c* in an Earth-Centered Inertial (ECI) frame, a frame that moves with the Earth but does not share its rotation. This constancy of the speed of light in the ECI frame is utilized in the GPS range equation given by [10]

$$\left|\overline{r_r}(t_r) - \overline{r_s}(t_s)\right| = c(t_r - t_s) \tag{7}$$

Here t_s is the time of transmission of an electromagnetic signal from a source, t_r is the time of reception of the electromagnetic signal by a receiver (both times determined using synchronized

clocks), $\overline{r}_s(t_s)$ is the position of the source at the time of transmission of the signal and $\overline{r}_r(t_r)$ is the position of the receiver at the time of reception of the signal. Equation (7) enables accurate determination of the instantaneous position of objects which are stationary or moving on the surface of the Earth.

This system provides us with the ability to test equation (5) by observing the actual time dilation resulting from clock movement. Let S correspond to the ECI frame and S' correspond to a frame moving relative to the ECI Frame. In the operation of the GPS, it has been rigorously confirmed that clocks that are stationary in S' run slow relative to clocks that are stationary in S according to the equation [8, 10]

$$t' = \frac{t}{\gamma} \tag{8}$$

From this, for the situation in Fig.1, the clocks in S' moving relative to those in S (which is the ECI frame of the GPS) experience a slowing of the time such that

$$\Delta t' = \Delta t / \gamma < \Delta t \tag{9}$$

This time change result is (along with other adjustments) continuously compensated for in the system programming such that GPS clocks remain synchronized, thereby enabling the system to operate successfully. Synchronization errors among these clocks of more than 4ns will result in navigation errors of more than a meter [20]. Now in this system for $\Delta t = 0$, from (9) we get $\Delta t' = 0$ which corresponds to absolute simultaneity and an experimental negation of equation (5). Thus, the GPS clocks confirm absolute simultaneity thereby showing that relative simultaneity does not exist.

The GPS network of synchronized clocks fixed on and moving (on satellites) around the Earth enables global or absolute simultaneity on or close to the Earth as these synchronized clocks are available across the globe. On this basis similar to an observation by Wang [21], two events at two different locations (x_1', y_1', z_1', t_1') and (x_2', y_2', z_2', t_2') are simultaneous if $t_1' = t_2'$. This is true between any frames whether stationary or moving relative to each other, on or close to the surface of the Earth. Relative simultaneity resulting in $t_1' \neq t_2'$ is never observed despite the relative movement of the clocks in the satellites. Indeed, if it existed, specific clock adjustment would have to be introduced in the GPS clocks in order to maintain clock synchronization and thereby prevent the system from being rendered inoperable. No such adjustment is ever used

confirming that relative simultaneity does not occur. It is an invalid prediction of an inconsistent theory that must be rejected.

4. Conclusion

In this paper we have shown that within the relativistic framework, both relative simultaneity and absolute simultaneity are predicted. This inconsistency disqualifies special relativity as a viable physical theory. Moreover, even though relative simultaneity has been accepted by the scientific community, it has never before been tested. The train-embankment thought experiment widely used to illustrate the phenomenon fails as it shows that simultaneity is not relative. The GPS enables experimental determination of the reality of the basic proposition and verifies that the idea is fictitious. This system requires and realizes absolute simultaneity in stationary and moving frames, and negates the concept of relative simultaneity.

Therefore, relative simultaneity is a non-existent phenomenon that, contrary to Will [22, p12], cannot be used to resolve the many "paradoxes" that challenge the consistency of the theory. Moreover, the Lorentz transformations given in equations (2) which are associated with this false prediction are invalid and must be replaced. The Selleri transformations [11, 23] given by

$$x' = \gamma(x - vt),\ y' = y,\ z' = z \tag{10a}$$

$$t' = t / \gamma \tag{10b}$$

which make all the verified predictions of the Lorentz transformations but contain none of its inconsistencies, are the transformations that best represent the physical world. In particular, these transformations unlike the Lorentz transformations predict absolute simultaneity that is demonstrated every day in the successful operation of the GPS.

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