Einstein's Famous Thought Experiment on Simultaneity Put to Test

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Abstract

Experiments to directly test relativity of simultaneity and relativity of spatial concurrence have already been proposed. In this eighth paper in the series of "Rudiments of relativity revisited", the famous train embankment thought experiment for simultaneity is analyzed under the new formulation of relativity, and the experiments on the same are proposed to differentiate between the two theories. Current relativity assumes a photon to be classically localized at an overlapped position in different frames leading to relativity of simultaneity, while the new relativity believes the particle exists at different positions in different frames due to relativistic non localization, leading to the relativity of spatial concurrence. New theory reproduces the so far proven results of special relativity besides predicting new experimentally verifiable phenomena unexplored so far.

1. Introduction

The current relativity (CR) [1,2] and the new relativity (NR) [3,4] both preserve the lightspeed. However, besides the two postulates of relativity, the NR also complies with the axioms of Kishori [3-6]. The new transforms (NT) are produced below along with the Lorentz transforms (LT) [5].

NT: $x' = em(x - vt)$, $y' = em_{\perp} y$, $z' = e\, m_{\perp} z$ (1)

$t' = e\, t$, (2)

where,

$$e = \sqrt{1 - v^2/c^2},\ m = \frac{1}{1-(v/c^2)(x/t)},\ m_{\perp} = \frac{\sqrt{1-v^2/c^2}}{1-(v/c^2)(x/t)} \quad (3)$$

LT: $x' = g(x - vt)$, $y' = y$, $z' = z$ (4)

$t' = g(\, t - vx/c^2)$ (5)

where g is the famous gama factor $g=1/e$, v is the relative velocity between the two frames whose spacetime coordinates are (x,y,z,t) and (x',y',z',t'). The temporal transform of NT, unlike LT, does not contain any x dependent synchronization term. NR and CR follow different schemes to map the events of one frame to the other. CR assumes the photons to be classically and relativistically localized, while NR asserts it is relativistically non-localized and hence exists at different positions in different frames (DPDF). Thus, NR successfully maps a set of simultaneous events to a set of simultaneous events in the other frame, discarding the relativity of simultaneity (RoS) and synchronization. The factor m in spatial transforms of NT is responsible for anisotropic spatial warping (ASW), relativity of spatial concurrence (RSC) and the relativistic non localization (RNL) as interesting aspects of NR [3,4].

Einstein proposed the famous train embankment thought experiment where simultaneous blasts occur in the rest frame of embankment across the two ends of a moving train and it is deduced that the blasts are not simultaneous for the moving frame observer (MFO) while they are simultaneous for the rest frame observer (RFO) [2]. In this thought experiment the observers are stationed at the origins of their respective frames away from the blast locations. Kishori's first axiom (KFA) objects to use such a setup that employs a single detector to observe multiple cross frame events for the fear of undesirable effects of finite signal speed (UEFSS) creeping into the relativistic framework. RoS and this experiment have already been scrutinized under KFA by using two synched separate detectors in the moving frame in the immediate vicinity of the blasts [3,7,8], and also experiments based on the direct detection of the flashes at the very sites of the blasts have been proposed to test RoS and RSC directly in our previous papers [8-9] in this series of 'Rudiments of relativity revisited', besides the other experiments that can verify the new tenets of NR [11-13]. Here, we consider the train embankment thought experiment in its original form that uses a single observer at the origin of each frame, to see if its outcomes as described in [2] are valid under the NR for the moving frame (MF). Experimental setups are detailed to test the outcomes of the originally proposed form without employing separate synched detectors at the very sites of the blasts.

2. Train Embankment thought experiment

According to NR, RoS is a fallacy of CR that results from three others: 1. Allowing UEFSS to creep into the framework of CR's relativistic physics. 2. Ignorance of ASW and RNL in the cross frame detections. 3. Tendency to proportionally estimate the distances traveled by the flashes in the moving frame from the directly mapped position of the flashes in the rest frame (RF) based on the overlapped position in the different frame (OPDF). We shall witness the same in the CR's analysis of the train embankment experiment.

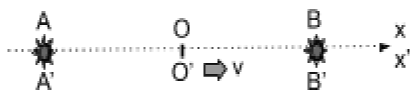

Fig 1a. Points A, B equidistant from origin O in the RF flash when points A', O', B' of the MF overlap with points A,O,B respectively.

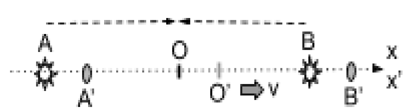

Fig 1b. At a time t = X/c. Flashes meet at O in the RF. Where do they meet in the MF?

First, Lali explains to Kishori one of the versions of the famous train (as a primed moving frame) and embankment (as an unprimed rest frame) thought experiment often used for establishing RoS [2], as shown in Fig 2. At time $t=t'=0$, the origins O and O' coincide, blasts occur simultaneously at points A and B of the embankment, which also happens to be the end points of a moving train $A'B'$ whose midpoint O' coincides with the midpoint O of AB, i.e. $OA=OB=AB/2=X$, similarly $O'A'=O'B'=A'B'/2=X'$. At time $T=X/c$, the rest frame observer (RFO) at O sees the flashes from A and B boh, confirming to him the simultaneity of the blasts in the rest frame(RF). Meanwhile, as O' has moved away from A towards B therefore it will see the flash coming from B earlier to the flash coming from A, confirming non-simultaneity of the blasts for the MF, and hence the RoS is established for a conventional relativist (CRist). With few variations, above is often the standard sequence of a CRist's arguments [2]. However, the moment moving frame observer (MFO) uses two synched detectors in line with KFA at the very location of the blasts A' and B', the RoS disappears under KFA [3,7] because such a setup ends the role of finite signal speed between the source and the detectors and hence reduces the chances of UEFSS.

In analysis above, CRist inherently assumes that if flashes meet at O in the rest frame they also meet at a MF point overlapping with O at the time of meeting of the flashes. As O has moved to the left for the MFO, it coincides with the point $-vT'$ of the MF at T', where T' is MF time when the two flashes meet. Thus, flashes travel unequal distances in the MF to meet at a point $-vT'$ that overlaps with O. Unequal distances traversed in the MF are translated as unequal times of origin of the two flashes in the MF. Kishori argues against such a straightforward back estimation below.

2.1 Limitation of Back Estimation: Let the events of detection of the flashes from the two blasts at O be $E1(0,T)$ and $E2(0,T)$, where the first number is the location and the second number is the time of detection. By back estimation, RFO declares the events of the blasts at A and B, namely $E1(X,0)$ and $E2(-X,0)$, to be simultaneous. The KFA in [3] warns that such a scheme of distant observation of multiple events by a single observer which may seem to work for the RFO is prone to UEFSS creeping into cross frame measurements. KFA proposes a set of separate detectors be placed in proximity of each event, directly recording their respective events. CRist argues that both schemes are equivalent. The single observer at *O* can estimate back and generate the time of all the events at their source from the numbers recorded in the scheme non-compliant with the KFA. For example, *E1(X,T-X/c)*, *E2(-X,T-X/c)* give the numbers when photons from the two blasts are still at their sources, back-estimated from *E1(0,T), E2(0,T)*, the set of numbers when photons have reached the origin *O*. The point is if we know the distance of the event-source, we can always back estimate the time of the event at its very source. Kishori stresses yes only if we know the distances unambiguously. For the unwarped RF, such a scheme may work, but for the detection of the same from the MF i.e. for cross frame detection due to relativistic spatial warpings it may mislead us, resulting in UEFSS to creep in the definitions of time and lengths. Therefore, we must avoid such a back estimation scheme for cross frame detections, at least until the laws of relativistic warpings of space and time free of any UEFSS are known. At this CRist smiles and claims the laws of relativistic warpings are already known and takes ahead the challenge to predict non-simultaneity of the blasts in the MF [2]. Kishori peacefully watches the CRist falling systematically in the fallacies of UEFSS with his each argument: Using LT he translates the RF event of meeting of two flashes at O at time *T* i.e. *E(0,T)* to the MF as *E'(-vT', T')*, deducing that the meeting point *O* in the RF is also the meeting point in the MF thus making the photons travel unequal distances in the moving frame before they meet. CRist thus ignores the NR-predicted ASW and DPDF that translate these seemingly unequal warped distances to be equal and the meeting point of flashes effectively to be at *O'* for MFO.

Let us apply NT to estimate distances traversed by the two simultaneously emitted flashes in the moving frame and see where the two flashes meet.

2.2 Applying new transforms

1. Distances traversed: From (2), when flashes meet at point *O* of RF at *T*, the corresponding moving frame time for both flashes is *T'=eT*. Thus using (1), NT generates equal distances, *X'=cT'*, travelled by both the flashes in the MF.

2. Meeting Points: Instead of origin, if particle starts its journey from *X* in the rest frame at time *t=0*, then its final positions in the rest frame is, $x_f = X + x$, and in the moving frame both *X* and *x* are separately transformed as in eq (23) of [5], to give

$$x_f' = e\{X + m(x - vt)\} \qquad (5)$$

Using *x=-cT* for flash from *E1*, *x=cT* for flash from *E2* in (5), the positions of flashes in the MF at a time *T'* comes out to be zero. Thus, while flashes meet at *O* in the RF, they meet at *O'* in the MF [8].

3. The setups to test the meeting point

Experiment to test RoS directly is already described in [3,8]. This experiment on meeting points of the simultaneously emitted flashes of fig. 1 can distinguish both CR and NR, and is also an indirect test of RoS.

3.1 Setup A

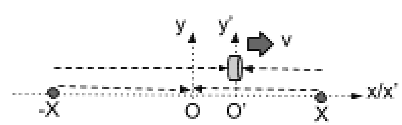

Fig 2. While pulses meet at O in the RF, they meet at O' on which placed a moving detector in the MF. O and O' aligned at the time of pulse emissions at X and -X.

Two sharp pulse emitting sources at *+X* and *-X* in the RF separated by a considerably large distance *2X* fitted with synchronized clocks that enable them to emit sharp but intense light bursts simultaneously at a time *t=t'=0* when y and y' are aligned, fig 6. As both NR and CR agree on pulses meeting at O in the RF at a time *t=T=X/c*, letus harness the origin *O'* (along y'-axis) of the MF with synchronized pulse detectors that can record the time of receipts of the oppositely directed pulses in the MF from their sources in the RF. We can also use two detectors placed back to back at *O'* both either controlled by a single clock or their respective clocks synchronized with each other.

Thus, MF consists of this doubly faced moving detector system (MDS placed at *O'*) that passes through point *O* at the time of emission of the pusles at time *t=t'=0*, which is not difficult to ensure. Suppose after taking the experimental errors into account the MDS records the receipt times for both the pulses as *ta'* and *tb'*. CR predicts a path difference of *c(ta'-tb') =2vX/c* for two pulses to reach at *O'* to a first order approximation. By increasing *v* and *X*, we can ensure that the cumulative experimental errors are much smaller than $2vX/c$. With such a setup, relativity of simultaneity (RoS) is refuted if

$$c(t_a' - t_b') << 2vX/c \tag{8}$$

thus, invalidating RFS.

Thus, within the experimental error limits $\varepsilon < 2vX/c$, if this measured path difference is found to be zero,

$$c(t_a' - t_b') = 0 \pm \varepsilon \tag{9}$$

then the tenets of strict NR like ASW, RSC and DPDF are validated once and forever, and CR and soft NR with unrevealed RSC are unequivocally refuted.

3.2 Setup B

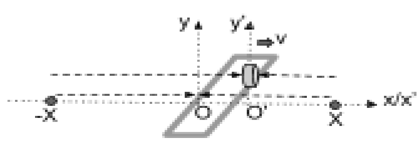

Fig 3. Setup two with a strip painted gray such that MDS is triggered twice when it passes over the gray strip once at O and next at O'. Moving system detects both pulses when it aligns with O' i.e. vX/c distance right to O, confirming that in MF the pulses meet at O' whereas in the rest frame they meet at O.

Even more effective way that frees us from stringent temporal measurement is based on spatially localized sensing of the pulse using spatially limited electric path or so called gray strips introduced in section 2 of [6]. Devise a rectangular gray strip, shown fig 7, such that the left side of it passes through fixed origin *O* and the right side lies at *x=vX/c* which is the position of O' when flashes meet at *O*. Think of gray strips as some engraved metal held at high voltage which enables the detection window of the moving frame detector (MFD) as it passes through it. MFD passes the right branch of strip at time, *t=T=X/c,* when *O* receives the two flashes simultaneously. CR predicts that the two pulses will reach at *O'* with a path difference of *2vX/c* while the NR predicts they reach with a path difference of zero. This gray strip can be a spatially limited EM field or simply a metal strip held at a high voltage, which triggers the MFD for a spatial window equal to its width *w*. For *w < vX/2c* will ensure that at *T*, MFD will miss both the pulses according to the CR but will receive both the pulses according to the strict NR. So, this right side branch of the strip suffices to prove the NR and refute the CR. However, we can run another MFD exactly *vX/c* distance behind the primary MFD at *O'*, so that this second MDS crosses over the left branch of strip passing through *O* at time *T* to exclusively conclude: while *O* receives the two pulses at *T*, this second MFD, though crossing *O* at time *T*, does not receive the two pulses thereby categorically negating the OPDF of the CR. Through repeated experimentation one can confirm that the primary MDS while at *O'* as shown fig 3, receives the two pulses as and when the stationary detector at *O* receives them, but the second MFD passing the left strip at *O* fails to do so.

The importance of this setup B over setup A is that here stringent temporal sensing window requirements are converted to spatially limited sensing windows. Obviously, the pulse width response window and cumulative path errors need to be << *vX/2c*.

5. Conclusion

Train embankment thought experiment which is most often used to establish RoS has been analyzed under NR. Both CR and NR disagree on the distances travelled and the meeting points in the MF of the two simultaneous emitted flashes in the

RF. Therefore, two experimental setups are designed and proposed on the lines of this thought experiment that can discriminate between the strict NR, and CR Papers [7-13] are our attempts to explore various aspects of the NR further. Paper [14] reinterprets and re-derives the LT, and the [15] extends the NT to static energy fields.

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