Relativity of Simultaneity Analyzed and Put to Direct Testing

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Abstract

The relativity of simultaneity and synchronization is considered as an underlying concept of the current framework of special relativity. However, it is deduced most often from the famous train embankment thought experiment, despite the fact the setups can be developed to test the simultaneity both directly and indirectly. Relativity of simultaneity is analyzed here as a concept separate from time dilation because the latter is reproduced by the new formulation of relativity without any need for synchronization term. It is shown that non-simultaneity is a result of assuming the existence of photons at overlapped positions in the two frames, which is supported by neither Lorentz nor new transforms. Experimental setups are proposed to directly detect the two blasts at their very locations.

1. Introduction

Current special relativity (CR) [1-5], which assumes relativistic localized existence of a moving particle, considers the relativity of simultaneity (RoS) as one of its fundamental aspects, while the new relativity (NR), which asserts relativistic non-localization, deems it as an undesired effect (UE) of finite signal speed (FSS) that creeps into the framework of CR due to its assumption of localized existence of photons, confusing linear order spatial warping as a temporal one. Thus, RoS does not withstand the scrutiny of the first axiom. Further in [6,7] a real domain framework of relativity is developed that reproduces the so far verified relativistic phenomena including time dilation without RoS and also predicts some new phenomena like relativity of spatial concurrence (RSC), relativistic non-localization (RNL), anisotropic spatial warping (ASW) and the existence of photon at different positions in different frames (DPDF) at a given instant. Further, RoS is a consequence of CR's assumption of a relativistically localized existence of a moving particle at an overlapped position in different frames (OPDF) which is supported neither by new transform (NT) nor by Lorentz transform (LT) [7], and it disappears under DPDF. RNL is the nonlocality across the frames, a bit different from the usual quantum nonlocality within a frame.

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

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

LT: $$x' = (x - vt)\ ,\ y' = y\ ,\ z' = z \qquad (3)$$

$$t' = (t - vx/c^2)\ , \qquad (4)$$

where,

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

$$m' = \frac{1}{1 + (v/c^2)(x/t)}\ ,\ m'_{\perp} = em'\ ,\quad = 1/e\ , \qquad (5)$$

and c is the lightspeed.

Further, LT and NT are equivalent but operate in different domains: LT in Minkowski or split domain, and NT in real or clock domain [6,8]. Thus, the neutral LT devoid of CR's interpretation does not contradict the newly proposed phenomena like DPDF, RSC and RNL. The RoS is often deduced using the thought experiments to view two simultaneous blasts of one frame from the other, first proposed by Einstein [1,2]. The direct test version of the same is proposed here. In indirect testing, the distant observers sitting at the midpoint of the locations of the two blasts, decide on the blasts' simultaneity for their respective frames depending upon if they receive the flashes from the blasts simultaneously or not [1,2,9]. Performing the indirect method in thoughts requires cross-frame estimation which is prone to UE of FSS. In the direct method of testing, the synchronized detectors are put closest to the blasts to detect the events of the blasts directly in each frame. The first axiom guides the direct testing setup with its two tenets: 1. *To avoid any UE of FSS from creeping into the estimated distances and times of one or more events, we must rely on a set of synchronized clocks and detectors positioned infinitesimally closer to the event-locations. 2. Consider virtually every point of a frame fitted with synced detectors, then the location of an event is the location of the detector in its immediate proximity and the time of its occurrence is the time recorded by that detector.*

2. Analyzing the RoS

Most often, the time dilation which is a second or even order effect in v/c is coupled with the RoS that depends linearly on v and x because in the Minkowski domain in which LT operates, the latter plays a role in arriving at the former. In the real domain, however, the NT produces time dilation without any need for a synchronization term. Thus in the real domain, RoS and time dilation are not coupled. Here, RoS stands in the limited sense that the two distant simultaneous events or synced clocks in one frame are not simultaneous or synced for a moving frame observer. The second misconception is that RoS is a direct result of the temporal transform of LT or the presence of synchronization term in LT. By that logic, the absence of RoS in NT must refute RoS automatically in the real domain. RoS is a consequence of CR's OPDF assumption, and the DPDF makes it disappear for both NT and LT as shown: Consider two photons originating at the common origin at $t=t'=0$ and triggering simultaneous blasts at x and $-x$ in the rest frame. If the moving frame observer assumes OPDF then to be at the blast-locations in the rest frame, the photons also have to be at the overlapped locations $\gamma(x-vt)$ and $-\gamma(x+vt)$ in the moving frame, which is only possible if different times are allocated to the photons, contradicting simultaneity of the rest frame. However, in the light of DPDF and the RNL-fact that the state of motion of the detector, which triggers the blast, affects the positions of the photons [7], such a contradiction evaporates as the sources of blasts are held in the rest frame, not in the moving frame at the above-overlapped positions, so the estimate of the rest frame prevails. Secondly, because of DPDF, when the photons were at x and $-x$ in the rest frame, they were not at the overlapped positions $\gamma(x-vt)$ and $-\gamma(x+vt)$ but at $x'=ex$ and $-x'$ in the moving frame as is obvious from the NT. This fact is also supported by LT because LT gives a very different time to occupy these overlapped positions in the moving frame [6]. Therefore, under DPDF both frames agree on the simultaneity of the blasts. Similarly, for the train embankment setup, the outcomes of OPDF and DPDF have been analyzed later for both indirect and direct methods.

The validity of directly testing the RoS

The last note here is about the validity of testing the RoS under the stipulation of constant-isotropic lightspeed in free space. A few physicists throw the following alibi against testing the RoS directly: as one-way lightspeed can not be measured so RoS can not be tested. The fallacy of this argument is obvious from the fact that even LT and RoS are deduced under the stipulation of the lightspeed-constancy in free space [1]. Einstein argues, it is possible to define a (unique) time of the frame like t, if the time taken by light from point A to point B of the frame is equal to the time taken to travel back from B to A [1]. Within a frame, the simultaneity exists, and we could have not talked of the non-simultaneity for the moving observer of simultaneous events in the rest frame or vice-versa without the stipulation of constancy and isotropicity of the lightspeed in free space in any given frame. Thus, RoS can be tested under the same stipulation on which it has been deduced [1,2]. Moreover, the synchronization of two clocks of the same frame is a fair assumption for both CR and NR under the constancy of lightspeed. However, to relax on the stringent needs of synchronization, we have described an equivalent setup using spatially limited detection windows at the end of this paper.

3. Cross estimation based indirect method

Before we analyze the indirect testing of RoS of fig 1, let us understand how indirect testing using a distant observer can be good for actual but not for thought experiments due to involved cross-frame estimation. It also helps to understand that the estimation is successful for in-frame detections, but not for cross-frame ones.

3.1 Blasting balls and a distant observer

Consider some balls lying amid the field blasting one by one due to heat, and an observer standing at a distance sees the visual act of blast happening before it is heard. The closer the observer moves to the blasting balls, the less is the time-gap he experiences between the visual act and the sound of the blast. This gap disappears when the observer places his visual and sound detectors in the infinitesimal proximity to the blasting ball. The observer has two options to conclude: He discards the time-gaps observed at a distance as an unwanted effect of finite and different signal speeds of light and sound and concludes on their simultaneity evident from his last observation when he placed his detectors in infinitesimal proximity of the ball. Or he proposes a theory that the nature of these blasts is such that the time-gap between the act and sound of the blast is a function of the radial distance of the observer from the site of the blast. But, here one can easily see the fallacy of the latter-proposition because in this case for every single distant observation, the first proposition can be proved by back estimating the time and locations traced back to the source. Had the speed of both the signals been infinite, there would have not arisen any need for back estimation, but unfortunately, no signal with infinite speed exists. Besides, the back estimation has also got its limitations. It works well in this case of in-frame measurements, where the blasting ball and the observer are in the same frame enjoying unwarped space between them. But the estimation is prone to fail in the case of cross-frame observation i.e. when the observer and the balls are placed in different frames. If the observer is both, away from the ball and also moving w.r.t the ball, then estimation or thought experiment is susceptible to failure.

3.2 The train embankment setup for RoS

Two simultaneous blasts flashed in the rest frame of the embankment at point *A* and *B* such that *AB=x* and *OA=OB=x/2* at a time when points *A*', *B'* and *O'* of the train coincided with *A*, *B,* and *O* respectively, where *A'B'=x'*, and *O'A'=O'B'=x'/2*, fig 1. Observers are at *O* and *O*' in the two frames. This experiment to indirectly test RoS has been analyzed in detail in [9], here we reproduce the main claims of the two theories. **CR claims:** The rest-frame observer at *O* receives the flashes simultaneously from the two blasts to confirm simultaneity in her frame. Meanwhile, the moving frame observer *O*' has moved to the right towards *B* and thus he will receive the flash from *B* first and *A* later to claim non-simultaneity of the blasts in his frame [1,2]. **NR claims:** CR being unaware of newly discovered phenomena like RSC, RNL and ASW, assumes the flashes exist at an overlapped position in different frames (OPDF) to arrive at an erroneous conclusion, whereas a photon exists at different positions in different frames (DPDF). Due to DPDF as flashes meet at *O* in the rest frame, they meet at *O'* in the moving frame, making the two blasts simultaneous in the moving frame too. Experiments to indirectly test RoS have been proposed in [9].

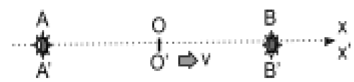

Fig 1. Famous setup for RoS. Points A and B in the rest frame are flashed when points A', B' of the moving train overlap with them. Observers O and O' in the two frames are also aligned at the time of flashing.

4. The proposition of direct detection

Consider each of the two frames, fitted with a dense matrix of identical, intrinsic synchronized clocks and detectors at virtually every point. *The clocks are synchronized with the clocks of their own frame independent and oblivious of the other frame.* These synchronized clocks define the 'unique time of their frame', which can be read by an observer from the clock next to her.

Relying on the synched clocks of her frame, the rest frame observer (RFO) triggers two simultaneous blasts at points *A* and *B* in her frame, which also happen to coincide with moving frame points *A'* and *B'* at the time of the blasts. Moving frame observer (MFO) using his own set of synchronized clocks and detectors at *A'* and *B'* detect the flashes at the very locations of the two blasts to test if the blasts are simultaneous in the moving frame or not. The only assumption made here in this proposition is that the clocks within a frame can be synchronized to give a unique time for their frame, which is quite fair under the constancy and isotropicity of signal speed. Mark it again that the observer synchronizes the clocks of his frame with any reasonable method justified for his frame, without bothering how it appears from the other frame or whether the observer of the other frame is convinced with it. Even if the observer of the other frame interferes to tell her that her method does not convince him, ask him that he should apply his convincing arguments to synchronize the clocks of his frame. The same is true for the other frame so that both frames end up synchronizing their clocks independently. One may ask about any preferred method to synchronize the two clocks of a frame. Under the constancy and isotropicity of the lightspeed, both CR and NR agree that the clocks of a frame can be synchronized for their frame, and thus any reasonable method can be employed to synchronize the clocks of the frame including the round trip method suggested by Einstein [1]. For simplicity of discussion, let us use any of the following ones: when a clock at *A* is reset to zero, it sends a light ray to set an identical clock at *B* to read x/c on the arrival of the ray, where $AB=x$, or send two rays from the midpoint of AB to trigger the two blasts at *A* and *B* in the rest frame.

Would the two simultaneous blasts in the rest frame be detected as simultaneous by the synched detectors of the moving frame placed in infinitesimal proximity to the blasts?

CR's analysis based on OPDF:
Consider the very synchronization process used to achieve simultaneous blasts in the rest frame. Clock *B* is kept x/c time ahead of clock A, but for MFO, the light has to traverse vx/c distance short of *x* for the moving frame as clock *B* also moves to the left, reaching vx/c^2 time earlier at clock B. Thus for MFO, the blast at *B* will happen vx/c^2 time before the blast at *A*, which exactly is the synchronization term in (4) of LT. Thus direct detection of the blasts in the moving frame will not be simultaneous.

NR's analysis based on DPDF:
CR, being unaware of the phenomena like DPDF, RSC, and RNL predicted by NR, follows OPDF to map the lightray's position of his frame to the rest frame and arrives at an erroneous conclusion, as it fails to filter out the UE of FSS in its cross-frame analysis. Due to RSC, the ray or the photon concurs with different locations in the two frames, and hence its position in one frame cannot be directly mapped to the other frame. Therefore MFO predicted positions of the ray are true for his frame but not for the rest frame, and similarly, positions of ray estimated by the rest frame observer (RFO) can not work for the moving frame because of DPDF. Based on OPDF, CR insists that to be at point *B* in the rest frame, the ray has to be at the overlapping point *B'* in the moving frame and vice versa, and obviously the times to occupy the overlapping points are different in the two frames, which CR uses to claim non-simultaneity of the blasts. But in the case of DPDF when the synchronizing ray is at *B* in the rest frame, it is at a very different point in the moving frame, not at all at *B'*. Another way to understand this is the following. Due to the RNL of NR, the position of detection is affected by the motion-state of the detector. Had the MFO put a detector in his frame at *B'*, it would have detected the ray there at his estimated time i.e. vx/c^2 before what RFO claims. However, clock *B* is stationed in the rest frame i.e.

in a different state of motion, and so it detects the ray exactly at *x/c* and not earlier. If the two observers realize that a photon is relativistically non-localized, and exists at DPDF, then the disagreement on simultaneity disappears.

Thus, NR and CR do not agree on the outcome of this experiment. The only way ahead is to actually do the experiment based on direct detection of the blasts at their very location.

5. Experimental setups to directly test RoS

Here, a practical setup to test RoS directly on the lines of the first axiom that states to keep detectors nearest to event-sources is developed. Let K1 and K2 be two stations having no relative motion between them, forming the rest frame (RF), as shown in fig 2. At *A* and *B* are kept two flashing sources controlled by well synchronized identical clocks or triggers in the RF, programmed to flash the sources simultaneously. The simultaneity of the triggers is to be achieved for the rest frame without bothering how they appear for the moving frame (MF). MF is formed by two oval identical moving detectors (MD) *A'* and *B'* which cross over the flashing points at the time of the flash and whose detection area is ovally elongated.

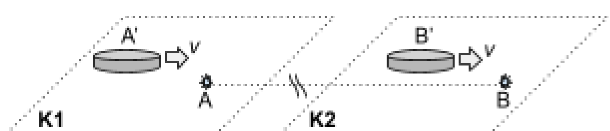

Fig 2. Setup1 to test RoS under first axiom. Moving frame's synchronized detectors at A' and B' pass over the vertical flash sources, A and B to record the time of the flashes in the moving frame.

Thus, instead of harnessing the whole moving frame with a dense matrix of detectors following the first axiom, we have smartly enabled the oval area around *A'* and *B'* with a detection capability, avoiding any misalignment of MDs with the source-points *A* and *B* beneath, due to second or higher-order warping. However, this oval broadening of MD must not affect their quick response, which has to be uniform across the area irrespective of where it is hit by the flash from beneath. Flashing sources are guided to flash vertically up, minimizing the lateral spread of light, and MD are tuned to receive this light hitting transversely from beneath. Detectors are equipped with identical well-synchronized clocks to record the time of detection in the moving frame and are subjected to identical moving conditions to ensure they remain synchronized throughout their journey. Again the MD are synchronized for the MF without bothering how they appear from RF. There will be practical sources of errors to disturb the otherwise expected simultaneity of the events in experimental. Suppose the time of detection for *A'* and *B'* are *ta'* and *tb'* respectively. The good news is that RoS demands a constant offset-interval, *c(ta'-tb') = vx/c*, for a given *x* and *v*, where *x* is the distance AB and *v* is the velocity of MD w.r.t the RF. So either by improving the experimental precision or by increasing *x*, one just needs to bring down the cumulative effect of all the errors well within a fraction of this constant *vx/c*. Repeated and reproducible measurements satisfying the path difference,

$$c(t_a' - t_b') << vx/c \qquad (6)$$

unambiguously refutes the RoS once and forever and if the same is proven to be zero within the experimental errors validates the no-RoS of the NR.

Improvised Setup2

To minimize the errors of synchronization between independently moving detectors, we can employ a spatially limited window of detection for both MD. The detection capability of MDs is enabled only when they cross over the gray metal or field strips running normal to AB, see fig 3.

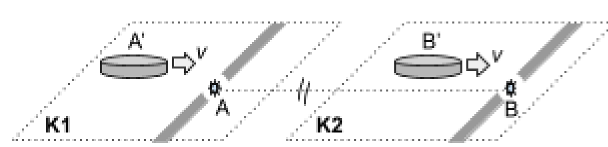

Fig 3. Setup2 to test RoS under first axiom. Moving detectors A' and B' are enabled by spatially limited gray metal strips engraved about A and B for a short duration.

Now if we also employ a pair of stationary detectors (SD) in the RF, positioned in the vicinity of the flash-sources such that these SDs are also enabled only when MD pass over the strips, then a successful detection of the flash by the MD and SD both will ensure the simultaneity of the flashes without running into the stringent requirement of synchronization of MDs. The physical Arrival of MD on the strip must electrically enable circuits of both MD and local SD to open a short window of detection. In the second case, the flashes are controlled by clocks synchronized in the stationary frame. But both SD and MD are enabled for a short duration on the physical arrival of MD. In [9] a setup to test the meeting point of flashes in the moving frame from the simultaneous blasts is developed.

6. Conclusion

New relativity is based on the NT that operates in the real domain, unlike LT that operates in the Minkowski domain. NT brings to light various new phenomena like DPDF, RSC, RNL, and ASW. NT and LT being equivalent transform operating in different domains, LT does not contradict the new phenomena. However, CR, which takes spacetime mixing in the Minkowski domain literally, interprets LT based on RoS, which is a consequence of the CR's inherent assumption of OPDF. It is shown that the RoS disappears under the new phenomena brought to light by NR such as DPDF and RNL. NR refutes the RoS, replacing it with RSC. In this paper, the claims of both theories are carefully analyzed, and the experiments to test RoS directly are proposed. Including this one, at least our six papers [9-14] analyze and propose various experiments that can distinguish these two formulations of relativity.

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References

1. The English translation by Meghnad Shah of Original paper by Einstein, Albert (1905), "Zur Elektrodynamik bewegter Körper", Annalen der Physik 322 (10): 891–921.
2. "Relativity, the special and general theory; the popular exposition", Albert Einstein 1932, translated by Robert W Lawson.
3. "Electromagnetic phenomena in a system moving with any velocity smaller than that of light", Lorentz Hendrik, Proceedings of the Royal Netherlands Academy of Arts and Sciences, 1904, 6: 809–831.
4. "On the dynamics of the electron", Poincaré Henri, (1905), Original: "Sur la dynamique de l'électron", Poincaré Henri, Rendiconti del Circolo matematico di Palermo 21 129–176.
5. "Space and time", Minkowski Hermann, Lecture 1908 original: Raum und Zeit, Jahresberichte der Deutschen Mathematiker-Vereinigung, 1-14, B.G. Teubner, a lecture delivered before the Naturforscher Versammlung 1908.
6. "Real domain transforms for special relativity", Solanki G.S., communicated.
7. "Relativistic physics of real domain transforms of special relativity", Solanki G.S., communicated.
8. "On the physics of interval and phase invariance of Lorentz Transform", Solanki G.S., communicated.
9. "Einstein's famous thought experiment for simultaneity put to test", Solanki G.S., communicated.
10. "Relativity of spatial concurrence analyzed and put to test ", Solanki G.S., communicated.
11. "Experiment based on the spatial shape of a transformed light-sphere", Solanki G.S., communicated.
12. "Exploring ultra lightspeed communication using relativistic non-localization", Solanki G.S., communicated.
13. "Relativistic non-localization based interferometer and lightspeedometer", Solanki G.S., to be communicated.
14. "Relativistic non-localization: an ignored phenomenon", Solanki G.S., communicated.