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INERTIAL REFERENCE FRAMES; AN INFORMATION-THEORETICAL APPROACH.

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ABSTRACT The paper discovers the informational basics of the inertial frames. It is shown that the usual description of physical processes, i.e. in spatial and temporal coordinates, would require an infinite amount of information, therefore the concept of "spacetime" is only a mathematical abstraction. Every transformation between frames requires information transfer. Depending on the form of information transfer, several transformation formulas are known (Galilean, Lorentz etc). However, these formulas have no physical background without information transfer.

KEYWORDS : Inertial Frames, Space-time, Coordinate Transformation

INTRODUCTION

In Classical Physics, we apply temporal and spatial coordinates to describe physical processes. This means, that these coordinate values are given *a priori,* (except General Relativity) with infinite precision. Even in Quantum Mechanics, all uncertainties are considered to be related to the particle's position and momentum, but not to the coordinate itself. Therefore, it is easy to see, that an inertial frame must contain an infinite amount of information. Whenever and wherever an event happens, the Frame "knows" its own time and space coordinates, moreover, without delay. In this picture, we don't need to have an "observer", or other auxiliary agent. therefore, we may call it as an "All-Knower", in Latin "Omnisciens" abbreviated hereafter as **"OS".** It is clear that an ideal inertial frame is a useful mathematical tool, but never can be realized. However, it is worth analyzing its properties, because we can recognize new relationships thereby.

1. The "All-Knower" (Omnisciens)

As already mentioned, an ideal inertial frame contains a huge amount of information. Therefore, it is reasonable to call it an All-Knower, in Latin Omnisciens, shortly **OS** in the followings.

An inertial frame is usually defined as an acceleration-free system. However, in order to define acceleration, we need the time and space coordinates before we set up them. To avoid a *circulus vitiosus*, a simple definition can be given based on a previous work of the present author [1]: An inertial system has no or negligible information exchange with its surrounds.

According to the above mentioned, an **OS** is equipped with the following appliances:

- A ruler to measure distances. Distance unit is arbitrary.
- An infinite number of synchronized clocks. Remember: even Special Relativity use a single time variable, which is valid for every location, within a given frame. This also means an infinite number of synchronized clocks, a somewhat unusual consequence.
- Not obligatory, but useful, and used in a great number of examples, if the frame has at each point a light source, a light detector, and a mirror.

FIG. 1 shows such a frame, the appliances shown at one location only.

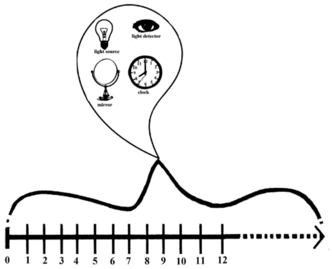

FIG. 1. The Omnisciens. An ideal inertial frame (OS), in one dimension. All locations of a ruler are equipped with a clock, light source, detector and a mirror.

2. Relation between different inertial frames

We can (in theory) construct several inertial frames. They are all equipped with the devices according to Fig. 1. The question arises: does any relationship exist between the coordinate values of these frames?

The answer is well grounded, but may be surprising for some readers:

if we have two or more inertial frames and there is no information transfer between them, then we can not prescribe any transformation formula. So, every kind of transformation (Galilean, Lorentz, "equivalent", etc) is a result of information transfer between the frames. As it will be shown below, we could get different transformation formulas, depending on the kind of information transfer.

In the followings, we fully accept Einteins Postulate #2 on the constancy of the light speed.

3. Contact information transfer

Both in Newtonian and relativistic physics, events play an important role. An event may be observed in two or more different frames, but with different coordinate values. The relationship is described by the coordinate-transformations, e.g. of Galileo or Lorentz. The question arises: are the inertial frames passive observers of random events, or can they initiate "events" themselves? The answer is: they can use their light sources for emitting a light pulse, which can be detected by an other initial frame. An information channel is built thereby. A special case among these transmissions, when the detector coincides with the source. This procedure can be called contact information transfer. On this channel, two inertial frames can share their data, such like clock time or ruler length. Unlike remote communication, the contact information does not depend on light speed.

The following operations may be performed:

- Unification of time and length measures. As mentioned, after the light speed equalization the quotient of the time and length units is the same in all frames. However, it is possible to equalize both units by contact information.
- Measurement of the relative speed. Two frames can measure their relative speed by sending two signals from the same location.
- The frames can match their zero positions.
- After executing these operations we get a normal Galilean transformation. As already stated above, we can not achieve any coordinate transformation between frames, just because a relative movement exists between them. Any attempt to derive Lorentz or other non-Galilean transformations use unjustified operations or does not have sufficient information.

4. Light speed between different frames

In the usual measurement of the light speed, both of the source and detector are in rest in a definite frame. However, in some cases, either the source or the detector is moving during the measurement. We call this case "Light speed between different frames." When this occurs, the question arises: what will be then the resulting light velocity?

There are several answers in scientific literature. Some authors claim that the light "takes on" the speed of the moving source, and the resulting light speed will be **"c"** plus or minus the source speed. Others declare an independency of the source speed.

As already mentioned, if we don't believe in a luminiferous medium, the light speed (as any speed) can only be determined with the source and the detector together. To show the behavior if the light in different frames , we apply the method of contact information transfer, as shown in Fig. 2.

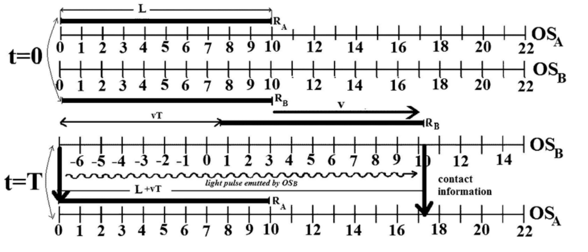

FIG. 2. Light speed in different frames. Frame **OS$_B$** sends a light pulse along a rod, and signals **OS$_A$** with contact information. The light pulse is detected at the end of the rod, and **OS$_A$** gets a signal again. Since both **OS**'s are inertial frames, where the velocity of the light is **c**, but **OS$_A$** respects itself as the preferred frame, it sees a larger light path than expected.

Suppose there are two **OS**'s, **OS$_A$** and **OS$_B$**. See Fig 2. We also have two rigid rods, both of length of **L**, (**R$_A$** and **R$_B$**). One end of the rods is fixed to the beginning of **OS$_A$** and **OS$_B$** respective. For simplicity, we apply one dimension again. **OS$_A$** is at rest, **OS$_B$** is moving with velocity **v**.

In the moment of **t=0**, **OS$_B$** emits a light pulse, and the same time sends contact information to **OS$_A$**.

After a time of **T=cL** the light signal arrives to the end of **R$_B$**. **OS$_B$** sends contact information again to **OS$_A$**. However, during this time, **OS$_B$** advanced a length of**vL**. It means that the pulse arrives in **OS$_A$** at **cL**+**vL**=(**c+v**)×**L**.

We see that the apparent light speed is **c+v** in **OS$_B$**, as seen from **OS$_A$**. If an observer in **OS$_A$** accepts the light speed constancy (Einstein's postulate #2) it is natural for him/her. However, if **OS$_A$** is believed the preferred frame, the observer may look for other causes, such as length contraction and/or time dilation in **OS$_B$**. As we will see, all discrepancies regarding the coordinate transformations arise from a disinformation: if a definite frame claims that it is solely the one where the speed of light is exactly **c**, because it is at rest relative to the (supposed) ether, then it is forced to suppose time dilation and/or length contraction in other frames.

This scenario is source of the so called "Linear Relativity" [3]

As can be shown, (see next Chapter) the amount of time dilation and length contraction is arbitrary, only their <u>product</u> is fixed.

5. Two-way light measurement

In the previous section, the light passed in one direction. The next scenario, frequently used in textbooks, uses a mirror. See Figure 3.

- **OS$_B$** emits a light pulse, at the same time and signals **OS$_A$** by contact information
- **OS$_B$** detects the light pulse, and reflects it with its built-in mirror
- **OS$_B$** detects the reflected pulse and transfers the information to **OS$_A$**
- **OS$_A$** gets contact information on the arrival of the light pulse
- **OS$_A$** noticed, that the light made a larger/smaller path than calculated

Let us calculate the travel times. In **OS$_B$** the total travel time is simply

$$t_{os2} = t1_{OS2} + t2_{OS2} = \frac{2L}{c} \qquad (5)$$

because the speed of light in **OSB** is equal to c in both directions.

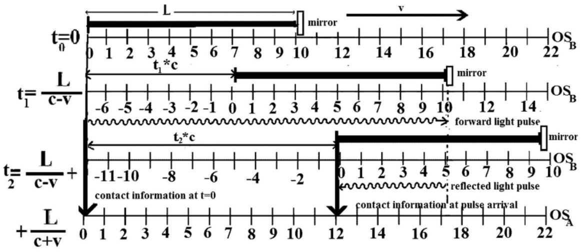

FIG. 3. Two-way light speed measurement. Frame **OS$_A$** is at rest, **OS$_B$** is moving with a speed of **v**. **OS$_B$** carries a solid rod of length L. At t=0 **OS$_B$** sends a light pulse along the rod, and gives contact information to **OS$_A$**. A mirror at the end of the rod reflects back the light to the emitting location. At arrival, **OS$_B$** sends contact information to **OS$_A$**. While **OS$_A$** respects itself the preferred frame, the flying time of the light differs from what expected.

Let us suppose, similarly to the previous example, that **OS$_A$** treats itself as the only preferred frame, therefore it supposes the light speed being in **OS$_B$** **c+v** and **c-v** respective, depending on the direction of the light beam. So, the <u>calculated</u> flying time is

$$t'_{os2} = t1'_{os2} + t2'_{os2} = \frac{L}{c-v} + \frac{L}{c+v} = \frac{2L}{c} \times \frac{1}{1 - v^2/c^2} \qquad (6)$$

Of course, this quantity differs from 2**L**/**c**, by a factor of $1/(1-v^2/c^2)$. A solution is again, if **OS$_A$** assumes time dilation and/or length contraction in **OS$_B$**.

The problem is how to share this factor between the time dilation and length contraction. Without including auxiliary conditions, no real answer can be given. A possible (but not the only) solution is to share the $1/(1-v^2/c^2)$ factor equally between time and length:

$$t' = \frac{t}{\sqrt{1 - v^2/c^2}} \quad \text{and} \quad x' = x \times \sqrt{1 - v^2/c^2} \qquad (7)$$

which leads to the famous Lorentz transformation. As mentioned, additional conditions are needed to derive any combination of dilation/contraction. An exhaustive collection has been compiled by J.H. Field [4]. Most of the derivations are based isotropy, uniqueness or space/time symmetry postulates.

CONCLUSION

In the present article inertial frames are investigated from an information-theoretical point of view. Communication between frames is described with full and partial information. Main findings:

- An inertial frame contains an infinite amount of information
- If some inertial frame treats itself as the only preferred frame, then apparent length contraction and/or time dilation arise. The measure of these (s. c. "Gammas") is depending on the actual configuration.
- In most cases the time dilation and the length contraction can not be separated. To derive the Lorentz transformation one needs additional information.

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