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Neste número:
tempo e espaço podem ser perfeitamente simétricos?

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uma geoengenharia possível.

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ARTIGOS ORIGINAIS

On Wick-Rotations and Quaternions: The Game of Symmetry between Space and Time

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Abstract: Despite so many advances, modern physics remains entangled in a number of open questions, some of which are responsible for considerable obstacles in the last 30-40 years. I belong to the group of those who consider that the biggest problem comes from instrumental and conceptual limitations. Our ways of understanding the universe are still extremely limited by the heritage of classical-positivist thinking. Moreover, it is not simple to break the constraints of a brain whose functional design has developed over millions of years in three-dimensional interactive evolution basically conditioned by the imperatives of survival. This natural resistance to a broad theoretical reconstruction leads us to advance very slowly through the innermost essence of the cosmos, having evident reflexes on our motivations and expectations. Present essay examines a preliminary model of spacetime structure in an attempt to offer new conceptual support for the study of the quantum entanglement. Wick-rotations are applied on a quaternionic basis to establish the theoretical foundations of the proposed spacetime symmetries.

Key words: Wick-rotation, quaternion, Clifford algebra, quantum entanglement, spacetime symmetries.

Resumo: Apesar de tantos avanços, a física moderna permanece enredada em várias questões abertas, algumas das quais responsáveis por obstáculos consideráveis nos últimos 30-40 anos. Eu pertenço ao grupo daqueles que consideram que o maior problema vem das limitações instrumentais e conceituais. Nossos modos de entender o universo ainda são extremamente restringidos pela herança do pensamento positivista clássico. Além disso, não é simples quebrar as restrições de um cérebro cujo *design* funcional se desenvolveu ao longo de milhões de anos de evolução interativa tridimensional, basicamente condicionada pelos ditames da sobrevivência. Essa resistência natural a uma ampla reconstrução teórica nos leva a avançar muito lentamente através da essência mais íntima do cosmos, tendo reflexos evidentes em nossas motivações e expectativas. O presente ensaio examina um modelo preliminar de estrutura de espaço-tempo numa tentativa de oferecer novos subsídios conceituais para o estudo do emaranhamento quântico. Rotações de Wick são aplicadas a uma base quaterniônica para estabelecer os fundamentos teóricos da simetria proposta entre espaço e tempo.

Palavras-chave: Rotação de Wick, quatérnio, álgebra de Clifford, emaranhamento quântico, simetrias do espaço-tempo.

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Prologue

The effort to understand the Universe is one of the few things that elevates human life above the level of farce and imprints something of the elevation of tragedy [17] [1].
Steven Weinberg

From the time I went through semiotics as a simple pupil of Umberto Eco [3], I never failed to emphasize the problems of language in science, particularly in physics, and its repercussions in the construction of theories. There is, of course, a philosophical discussion behind linguistic criticism insofar as philosophy is an excellent tool for perfecting our ideas. Adding to all this the understanding of everything that has been said about

[1] Free author's translation.

the dimensionality of the world, about space and about time, I would say that we have at hand an excellent cornucopia of doubts. As Simon Brissenden said recently on the way time is thought after Einstein's relativity,

The language we use and the culture we have been raised in, are profoundly Newtonian and it is difficult to adjust to thinking relativistically [2].

One of the questions that has always instigated me is whether space and time can be put on the same operational footing, that is, whether we can formally work in the same way with both concepts. With respect to the understanding of what time is, although we see in current literature a kind of disguised conformism to the ineluctable difficulty of assimilating it as a real physical quantity, there is no generally agreed upon how to define it rigorously in the same status of the space.

The idea of a complete unity between space and time has long germinated. In fact, it is a time-consuming process of maturation, ranging from the most naive ideas to the less tangible representations of abstract intellection. Hegel, for example, already showed signs of a lucid philosophical perception of reality regarding the apparent separation between space and time:

Sublimiore autem geometria, quae geometriae calculum analyticum jungit, at ex ipsa necessitate temporis spatiique unitorum rationes emetiendi orta est, separationem nonnisi negative per notionem infiniti tollente, neque utriusque veram synthesin proponente, et in negotio suo a formali geometriae et arithmeticae methodo neutiquam discedente [4][1].

He makes clear not only the need for a *spatio-temporal* synthesis, but also the fact that this synthesis had not yet been reached. I think Weil was the one who came very close to do this for the first time in 1922, the year of his seminal work "Space, Time, Matter" [16], although the former serious step toward what might be said the "perfect symmetry" between space and time has been given by Locke, well before Hegel:

[...] expansion and duration do mutually embrace and comprehend each other; every part of space being in every part of duration, and every part of duration in every part of expansion [5].

As much as we think of space and time as inseparable, there remains in our minds a feeling of incompleteness, an intellectual emptiness as to the understanding of the type of symmetry of that combination. This is mainly due to the fact that common sense does not conceive an image by which time and space can be placed under a single broader construct. Even the "amalgam" popularized from Einstein's theory of relativity does not explain a visceral relationship between its constituents (since establishing a pseudo-Pythagorean framework in four coordinates is not in itself sufficient to characterize a perfect symmetry between space and time), or to what extent we can refer to the blend of space and time as not artificial.

Once, a student interested in cosmology and astrophysics asked me if it was possible to travel in time, to which I replied: "If so, we shall need an exotic theoretical model to try to understand how can something transit freely between the ages. We shall probably have to rethink spacetime in the fashion of quantum mechanics, facing paradoxes and restricting our approaches to the limits of information theory" (after all, the idea of transmitting information to the past or to the future is far less pretentious, rather than sending people to Ancient Rome or the Jurassic). I mention this because I think that the shift in time is an excellent paradigm for discussing how space and time could exhibit perfect symmetry. By perfect symmetry I understand the possibility of switching roles played by two interconnected distinct objects.

My research perspective is cosmological and quantum-mechanical, since the theory of quantum spacetime I advocate describes how the cosmic web evolves. There is still much speculation in astrophysical cosmology, even though objects of cosmological importance such as type I-A supernovae remain the subject of extensive studies, as well as the interior of black-holes and the center of spiral galaxies. But, I believe that such speculations, as long as they are inscribed in erudite plausibility, may flourish at some point, whether by observational discoveries or laboratory procedures. It may be that time travel is a matter of perfect symmetry between space and time, if such symmetry exists. In at least one notable instance, it could be true an effect of such a symmetry: the quantum entanglement.

The notion of symmetry is very broad, playing a fundamental role in physics. Particularly, I like the example stemming from Maxwel's remarkable groundbreaking contribution by which one came to understand that a changing electric field generates a magnetic field, and, on the contrary, a changing magnetic field generates an electric field. There is also the beautiful symmetry between bosons and fermions, called supersymmetry, over which I have worked for some years. Supersymmetric theories allowed us to overcome some dichotomies; thanks mainly to supergravity, we obtained the benefit of the symmetry between "matter" (semi-integer spin particles) and "interaction" (integer spin particles). I wonder if space and time would exhibit such a powerful symmetry, capable of manifesting itself through phenomena we do not even suspect.

[1] The superior geometry which results from the fusion of analytic calculus with fundamental geometry, and which arose from the same necessity of measuring the relations of time and space together, overcomes this separation only in a negative way, by means of the notion of infinity, but does not propose the true synthesis of both [...] (free author's translation).

My intention in this essay is to discuss a proposal of spacetime supersymmetry (or perfect symmetry), considering some semantic implementations in the formal language of the theory and specifying under what conditions such supersymmetry could be verified. Whether in the future such representation shall serve as the basis for technological implementations that make some sort of temporal transport possible is a question I do not propose to risk an answer.

II PART: THE WAKE OF THE SCHISM

1 A bit on Wick-rotation

A very puzzle in modern science, while obsequiously left aside, is to find a physical meaning to justify Wick-rotation, a mathematical procedure said by many to be no more than "a mere technical trick". There has been a time when I devoted extensive efforts to the study of the physical significance of Wick-rotation. So, I will allow myself to reproduce a part of my records here, adding some important updates.

The application of Wick-rotation is in such manner confuse that in many works I was even unable to resolve whether the authors were discussing having in mind Lorentzian or Euclidean signature; indeed, I could not see any clear justification with physical significance to introduce imaginary rotations in those discussions. Excepting the few one can find on Wick-rotation applied to the momentum variable k_0 in Green's functions, no remarkable reference has been done, especially about the possible roles fulfilled by bosons and fermions in Wick-rotation (concerning peculiarly the fermions, this was noted also by Nieuwenhuizen and Waldron [**?**]). Even in early quantum physics, the imaginary unit is hollow of physical significance. As an example, concerning Pauli matrices, we see that physicists like to put them in one-to-one correspondence with orthogonal directions in Euclidean 3-space, expressing their orthogonality by the Grassmannian outer product $\sigma_1 \wedge \sigma_2 = \sigma_1\sigma_2 = -\sigma_2\sigma_1$. Thereby, the product $\sigma_1 \wedge \sigma_2 \wedge \sigma_3 = \sigma_1\sigma_2\sigma_3 = i$ reflects the identity between i, as the pseudo-scalar unit for Euclidean 3-space, and a trivector created by the outer product of the orthogonal vectors σ_1, σ_2 and σ_3. Everything is accepted tacitly as a mere formal result. Also in twistor theory, no direct physical interpretation is generally assigned to the complex coordinates. By the way, recalling Clifford algebras, we see that a reflection related to a plane orthogonal to γ^a is given by $\psi \Rightarrow \gamma^a\psi$ in spinor space, and for time-like γ^a we must substitute γ^a by $i\gamma^a$ to satisfy the imposition of identity for squared reflections, indeed a beautiful feature but much more connected to mathematical modeling than to physical requests (I am trying simply to show where we may be more emphatic about physics). Finally, discussing Higgs mechanism for gravity and considering a Lorentz violating spectrum in a model for non-massive gravitons, scientists are once more laconic about the imaginary frequency at very low momenta. After all, a complex number can always be used to register a spinorial association, since the coupling of "i" specifies a twirl,

$$\underbrace{a + i\overset{\overset{spin}{\downarrow}}{b}}_{complex\ number.}$$

Surely, no one else imagines a real rotation in the quantum world. The spin is not a "thing", but only a symbol denoting a type of symmetry belonging to a class of symmetries of which Cartesian rotation is a trivial example.

In 1977 there appeared an interesting work of the French physicist and philosopher of science Jean Émile Charon, *Theorie de la Relativité Complexe*, in which he proposed a complex quadridimensional Riemannian structure to the physical space with a metric

$$Z_{\alpha\beta} = \tilde{Z}_{\alpha\beta} + i\breve{Z}_{\alpha\beta}, Z_{\alpha\beta} = Z_{\beta\alpha}, \tag{1}$$

so that,

$$ds^2 = Z_{\alpha\beta}dy^\alpha dy^\beta, \tag{2}$$

with

$$y^\alpha = \tilde{y}^\alpha + i\breve{y}^\alpha. \tag{3}$$

Charon argues, among other ideas, that only such a complex space turns possible to extend general relativity to quantum field domain and justify the four complex extra components (including time) as a way to assign physical quantities to the theory (for example, the action associated to the spin)[2] . Unfortunately, the theory did not gain the merited attention.

John G. Taylor, at the height of his career, ascribed physical interpretation to imaginary quantities when he wrote the third chapter of "The New Physics", entitled "Faster Than Light". Telling us about Einstein's famous article of 1905, we may read at page 94 of the Spanish version:

... si acelerar una partícula hasta la velocidad de la luz exige una cantidad infinita de energía, acelerarla por encima de este valor requerería una energía imaginaria. Una cantidad imaginaria está formada por el producto de un número real y la raíz cuadrada de menos uno. Aun cuando esta cantidad puede manejarse sin mayor problema como símbolo, en la realidad no resulta posible medirla (Taylor, 1974).

Here, an imaginary physical quantity is one to which there is no sense to apply rules or clocks; is one to which observational operations are not defined. Even so, it is

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[2] J. Charon, "*Theorie de la Relativité Complexe*", Albin Michel, Paris (1977).

considerably present within the frame that explains the world.

Also, it is worth remembering the probability distribution in quantum field theory, or, as it is better known, path integral. According to Baez, the amplitudes of probability are proportional to $\exp\left(-S/i\hbar\right)$, giving to quantum world an obscure feature if compared to statistical mechanics, where Boltzmann distribution $\propto \exp\left(-E/T\right))$ arises naturally from the principle of maximum entropy.

The introduction of the imaginary unit through Wick rotations may be indirectly associated with physical mechanisms of mass acquisition in the supersymmetric relationship between bosons and fermions. Parallel to Higgs's anticipated description of such a mechanism in terms of a boson, I had some interesting insights during my investigations on supergravity.

For now we know only one boson of Higgs, which does not mean that there are no others. Years ago I established a supersymmetric model of gravity with gravitinos confined inside an anti-De Sitter spacetime. The boundary between this spacetime and the De Sitter universe where the gravitational interaction mediators (gravitons) inhabit is actually a field I have called "filtrinic" (relative to a hypothetical particle called "filtrino"), which is the barrier whose "toll" to be paid by an escaping gravitino is its own mass; if "decides" to pay it, gravitino will lose his identity becoming a massless graviton. The filtrino, the hypothetical semi-integer spin particle correlated to the junction field between the two spacetimes, retains gravitino mass, but for a short time as soon as a graviton penetrates the junction and becomes a new gravitino in the anti-De Sitter spacetime. In fact the massive filtrino interacts with the gravitational field through its emissary (graviton) to generate a gravitino. Reverse operation reveals perfect symmetry between graviton and gravitino, since inversely a gravitino interacts with the gravitational field to generate a filtrino. We can see that the junction field is a kind of exotic gravitational region originated from the separation between two fundamentally distinct spacetimes, where the filtrino is an ephemeral fact. For the representation of this mechanism in terms of a spinorial-like matrix formalism, the application of Wick rotations has proved extremely convenient.

Not exactly in the same reasoning line, but in a certain way similar to my above considerations, Nieuwenhuizen and Waldron proposed "a continuous Wick-rotation for Dirac, Majorana and Weyl spinors from Minkowski spacetime to Euclidean space, which treats fermions on the same footing as bosons" [7]. They emphasize that the study does not focuse the Wick-rotation of the momentum variable k_0 but a Wick-rotation of the field theory itself. After some observations, they were led to suggest for a Dirac spinor the Wick-rotation

$$\Psi(\tau,\vec{x}) \rightarrow \mathtt{S}(\theta)\Psi_\theta(\tau,\vec{x}), \tag{4}$$

$$\Psi^\dagger(\tau,\vec{x}) \rightarrow \Psi_\theta^\dagger(\tau,\vec{x})\mathtt{S}(\theta), \tag{5}$$

in which $\Psi_{\theta=\pi/2} \equiv \Psi_{\mathrm{E}}$ is the Euclidian Dirac spinor and $\mathtt{S}(\theta)$ a diagonal matrix with entries $(e^{\gamma^4\gamma^5\pi/2}, 1, 1, 1)$ that acts only Wick-rotating time sector (the exponents γ^4 and γ^5 are elements of the Euclidean Clifford algebra). Resembling argumentations are applied to Majorana and Weil spinors.

Lately, Matt Visser [15] made an interesting discussion on Wick-rotations in flat spacetimes, recalling the "$i\epsilon$" prescription for quantum field propagators as an elementary consequence of causality in Minkowski space, and showing that the simple procedure of an analytic continuation of the time variable, "$t \rightarrow it$" — which agrees only in cases like the Minkowski and Schwarzschild static metrics —, does not offer a consistent generalization for all curved manifolds. In continuation, he obtained an interpretation capable of providing a nice generalization. The reader will find curious the formal coincidence, albeit in very different contexts, between the approach in reference [15] and my approach in terms of a complex "not quite Minkowskian" metric, made below.

In analogous sense, as we may define a dual field ϕ_D and a dual function $F_D\left(\phi_D\right)$, so that $\phi_D = F'\left(\phi\right)$ and $F_D'\left(\phi\right) = -\phi$ constitute a Legendre transformation $F_D\left(\phi_D\right) = F\left(\phi\right) - \phi\phi_D$ or, which came to be the same, a duality symmetry,

$$\begin{pmatrix} \phi_D \\ \phi \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \begin{pmatrix} \phi_D \\ \phi \end{pmatrix}, \tag{6}$$

we have in gravitorial theory [11] a symmetry

$$\begin{pmatrix} \boldsymbol{i}_2 \\ \sigma_\eta \end{pmatrix} \rightarrow \begin{pmatrix} \gamma_{\overline{11}} & \gamma_{\overline{12}} \\ \gamma_{\overline{21}} & \gamma_{\overline{22}} \end{pmatrix} \begin{pmatrix} \boldsymbol{i}_2 \\ \sigma_\eta \end{pmatrix} \tag{7}$$

for gravitinos or,

$$\begin{pmatrix} \mathbb{1}_2 \\ \sigma_\mu \end{pmatrix} \rightarrow \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix} \begin{pmatrix} \mathbb{1}_2 \\ \sigma_\mu \end{pmatrix} \tag{8}$$

for gravitons. In this theory, according to my way of seeing, Wick-rotation is a particular kind of abstract representation that serves very well to explain isometric transformations with physical significance, puting face-to-face, in a simple manner, the state-object and its qualitative change. It preserves a great mathematical inheritance, as we deal with the so intuitive and powerful idea of rotation group but, at the same time, warrants that "something" is no more the "same thing" from the viewpoint of system's physics under isometric isomorphism. For instance, when we Wick-rotate a bosonic representation, we are bringing a fermionic one but in a unique affine frame because $S(g) = iS(g)$.

1.1 Explaining the problem

What must be clear to the reader is that I do not intend to sound identification chords with science fiction ideas (although I appreciate the genre). The discussion here concerns phenomena of the quantum world, having nothing to do with anthropic fantasies; I only wish to work on a conjectural level that may be useful in future works following Popper's thinking, according to which

[...] Risky ideas, unwarranted anticipations, speculative thinking, are the only means we can use to interpret nature: our only "organon", our only instrument to apprehend it. And we must risk ourselves, with these means, to achieve the prize. Those who are not willing to expose their ideas to the eventuality of refutation will not participate in the scientific game[3] [8] (free author's translation).

I also think that space and time in its most intimate connection constitute a phenomenon that transcends any help that perception can give us. Nothing better than an excerpt from Merleau-Ponty (regardless of he may have been confused about some aspects of Einstein's theory of relativity), following Husserl's ideas, to summarize this thought:

[...] every effort to understand the spectacle of the world from within and from the sources demands that we separate ourselves from the effective unfolding of our perceptions and our perception of the world, that we be content with its essence, that we no longer confuse ourselves with the concrete flow of our own life to retrace the whole movement and the main articulations of the world upon which it opens. To reflect is not to match the flow from its source to its last branches; it is to get rid of things, perceptions, the world and perceptions of the world [6] (free author's translation).

My theory starts from two basic questions: is there such a symmetry (a perfect symmetry) between space and time that makes possible information traffic from present to future as well as to past? And if so, is there a phenomenon that insinuates this possibility? According to my interpretation, a perfect symmetry between space and time determines that both can be converted into each other. In other words, the reverse of space is time, and vice-versa. To answer the second question, the only phenomenon we have at hand to help us to justify such a transformation is the quantum entanglement. But, if spacetime can suffer that presumed role reversal, it is reasonable to assume that this reversal begins with quantum entanglement itself, since entangled particles, separated by an arbitrary distance, change their behavior simultaneously as if they broadcasted freely between past and future. The role reversal, I believe, occurs at the moment of quantum entanglement [2].

[3] However, there must be a balance between the need for risk and the usefulness of the risky idea. For example, although we do not have direct access beyond the event horizon, there is no evidence that we should abandon Einstein's equations to describe the interior of a black-hole, at least as long as we keep away from the quantum of spacetime that characterizes its central singularity (as I discussed in another paper, the notion of point has no physical meaning, the reason why it is necessary to specify the quantum of spacetime defined under the action of an intense warp energy).

1.2 The quantum of spacetime

For the discussion that follows, it is interesting to note that the refutation of the old "ether" by the theory of relativity has not eliminated, as many people think, the idea of an absolute space. In fact, space preserves its physical properties, since the equations of motion for material bodies and force fields have not the same form in translational and rotational frames. Thus, what really should be removed from physics is the Newtonian notion of an immovable "container-space" that existed as a frame of reference in absolute rest. This reminder is crucial, because by assigning a sub-Planckian quantum dynamic structure to spacetime, I am postulating its own physical existence.

The ontological limitation of the spirit is remarkable when it comes to describing spacetime; it presents itself sometimes as a fact determined by the mode of relationship between objects, sometimes as a substratum of all that exists. I believe we should embrace both understandings, applying them as required in different thinking situations.

For the first case, if we compare the spacetime in which we live with the spacetime where the entangled particles supposedly live, the following logical reasoning can be supported:

Spacetimes are just states manifested by the ways objects and sets of objects relate to each other; thus, ordinary spacetime, which reflects the observable universe, is the state that results from the way in which the objects we know interconnect, influence, dispose in relation to each other, destroy one another, or merge into new ones. In this everyday spacetime, time is one-dimensional; only future linked to a fixed past.

In Wittgenstein's saying, if more cannot be said, it is better to be silent!

For the second case, let's look at the problem from a physical point of view. In a recent work, I discussed (in French) a question that seems to me to be at the root of the difficulty of reconciling quantum mechanics with general relativity. While cosmology seeks to understand the genesis of the universe, *inter alia*, from an expansion dynamic that, in principle, does not indicate any discontinuous character of spacetime, quantum mechanics reveals the character discrete of the microphysical structure of matter. In my opinion, this discrete image is only what is captured from interactions, and Rovelli is right when he emphasizes interaction as a key concept for understanding the world (note that this conclusion goes well with the previous logical reasoning). But when one speaks of the ultimate tapestry of the universe, of the most intimate content of all matter, it would be a philosophical contradiction to establish an indivisible matter, since the indivisible does not consist in parts, and what has no parts has, theoretically, the nature of a point. But the point is a pure mathematical abstraction; it is now time to remind ourselves that matter is ultimately made up of spacetime itself. So, the most logical way to conceive physical reality is to imagine a dynamic continuum formed by infinitely small expansions or contractions. The dynamic continuum cell, expressed by a quantity as small as you wish, is the quantum of spacetime; no matter how small one can imagine it, it is still smaller, and again smaller, not because it is inaccessible to the rules, but because its dynamics runs in the domain of the infinitely small steps. In this way, the infinitely small translates into spacetime expansions or contractions, as small as one wants, not into abstract intervals of a static geometry. I understand that, most likely, what we call "dark energy" is the energy dissipated by these infinitesimal fluxions. Such an approach, however, is not part of this essay. The fundamentals of the spacetime quantum theory I advocate are found in the references [10] and [12].

Certainly, the human being has no intellectual capacity to fully understand the discussed symmetry, just as the phenomenon of quantum entanglement escapes common reason. It seems even unlikely that we can test such symmetry within the limits of the existence of mankind. It would be necessary, then, to detect some physical phenomenon for which a satisfactory description could be constructed from the proclaimed mutual inversion of roles between space and time.

II PART: QUATERNIONIC MODELING

2 Seeking to model quantum entanglement

Quantum entanglement generates an odd interaction between particles, a kind of linkage that has no equivalent in classical world. Two ways are possible to understand entanglement: 1) from quantum computing, introducing an imaginary quantumfold, a onefold that only exists in quantum descriptions of nature, from which we may obtain an imaginary representation of entangled states by tensor operations applied on it (this quantumfold is not geometrically thinkable, so that it is covered by a special and unique tensor product to one qubit)[4]. To extract real entangled states from this type of coverage we logically need one imaginary gate; 2) from supersymmetry, swiveling spacetime to change the roles of the components of the coordinate basis. I will deal with the second option, as I have considered the first in a previous work [13]. Let's think for a moment about the meaning of attaching the imaginary unit to any quantity. We may suggest that we are applying a marker on a variable that can not be measured (but yes, on which we can virtually and artificially lead a counting). This seems to be the case with time; we can count it abstractly with a clock or an hourglass. We cann't, however, measure it in the strict empirical sense of putting an interval of duration next to a ruler; it does not exist the perception of "spacing" with respect to time.

Now, suppose that the physics as close as you want to a pair of entangled particles can be described from a four-dimensional coordinate system similar to the Minkowskian system. Let's go back a little to discuss the pure coordinate basis including the markers that will be coupled later to variables, assigning to them temporal or spatial signature. Before an observation (in the experimental sense of the word), there is no logical reason to attribute spatial or temporal signature to a given value belonging to a *Gedankenexperiment* in that vicinity. All we can do is to manipulate the basis by some algebra and see how the markers transform by the algebra. The possible transformations are the symmetries of the theory.

We are next bound to ask: what is the three-dimensional time? It would be more natural to conceive it in two dimensions: past and future! However, a little theoretical acuity makes us realize that the present is also a dimension if we understand that, in a causal line, it is a variable that is very committed to the future and, retroactively, to the past. The present, this fleeting flash, contains the state of the observer, a moving horizon of reference. A curious illustration would be as follows: if we look at the sun, we will have a picture of the past; in the opposite direction, it can be said that the sunlight which has just passed us, going into the future, gives us the past of the future from the wall of a building we are watching, illuminated by that light, that is, the future of the building with a certain "discount". But we are "the present" as observers, and we can shift this present to see a farther past of the sun and a near future of the building (or a shorter separation between building's past and its future), even though the system as a whole head always to the future. Past, present and future are then very dynamic and intertwined! This may sound unintuitive, but contemporary physics is very filled with nonintuitive things. A categorical example of the presence of unintuitive elements at the heart of the fundamental principles of one of the most important scientific theories ever is the trajectory of a light ray. According to Einstein's theory of relativity, following Bertrand Russell's excellent approach (2018), light describes trajectories from minimal paths, which means that between two neighboring points of a light ray the distance is zero (null geodesic) [9]. Still, there is a temporal difference between the two points, such that there are intervals closer to the source than others (all this, and more precisely the concept of null geodesic, in full agreement with my quantum theory of spacetime). This is a logical result of the conception of spacetime, from which space and time no longer separate as in Newto-

[4] In fact, entangled particles respond to each other at the same time, being separated only in ordinary space, but solidly bound, embedding with one another in the quantumfold.

nian physics.

2.1 Wick-rotating quaternions

As suggested earlier, it can be said that one of the gaps in current mathematical physics is the attribution of a direct physical meaning associated with the imaginary unit. In addition to the meaning discussed from expressions (7) and (8), there is a more effective way of introducing the imaginary unit as a physical marker. Particularly, I will propose a tentative model to deal with the hypothetical perfect symmetry between space and time, in which such a direct physical meaning is attributed to the coupling of the imaginary unit.

We consider a base with four coordinates (X_0, X_1, X_2, X_3) with an *a priori* condition: as close as you want to the pair of entangled particles at the moment of its creation, you do not know what coordinates are, whether timelike or spacelike; those coordinates form a quaternion. A *CIS*-temporal quaternion (C) is Minkowskian, that is, constituted by a temporal component and three spatial components; a *TRANS*-temporal quaternion (T) is formed by three temporal coordinates and one spatial coordinate. For simplicity, I call *CT*-quaternion the pair (C, T). Also for simplicity and to avoid confusion, I call "fourth dimension" the component that unidimensionally characterizes space or time. Since I will deal only with the transformations of the quaternionic spacetime base, exemplifying with 2X2 abstract matrix representations, I will adopt arbitrary arrangements constructed from Pauli matrices, which will certainly be useful in further studies.

Firstly, before going on to investigate quaternion transformations, we assume that operators i, j, k map reals to imaginary numbers; the polarity of the i, j, k-axis can be freely fixed according to whether Wick-rotation comes from i, j, k rotating in clockwise or anticlockwise direction. In addition, we must remember that mathematical properties of rotational operators both in 2D and 3D systems are invariant over changes of axial parity [14]. Lastly, imaginary time is a concept that plays crucial role in our understanding of exotic phenomena; Thus, it looks promising to expand the concept to try to explain a phenomenon so exotic as the quantum entanglement.

Now, let the *TRANS*-quaternion coordinates base be equal to $\left(\mathbb{1}, i\sigma_{(k)2}, j\sigma_1, k\sigma_1\right)$, where i, j, k are imaginary units, $\mathbb{1}$ is the unitary matrix 2X2, $\mathbb{O}$ is the zero-matrix 2X2, and $\sigma_{\dots}$ are the Pauli matrices,

$$\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},$$

$$\sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix},$$

having in mind that it makes no difference if we use k or j instead of i, and

$$\sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix},$$

remebering that to define upon a particular 4-dimensional configuration of co-ordinate axes a system of rotational operators which has the property of being non-commutative leads us to the following relationships between the operators:

$$ij = k; ji = -k;$$
$$jk = i; kj = -i;$$
$$ki = j; ik = -j.$$

So, the transformation

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & +k \\ -k & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \begin{pmatrix} +\mathbb{1}_2 \\ +i\sigma_{(k)2} \\ +j\sigma_1 \\ +k\sigma_1 \end{pmatrix} = \begin{pmatrix} +\imath\mathbf{i}_2 \\ -\sigma_1 \\ -\sigma_1 \\ -\sigma_1 \end{pmatrix}, \quad (9)$$

is a Wick-rotation of the *TRANS*-quaternion giving a *CIS*-quaternion. Pauli matrices are always useful, because they generate the observable subspace of the two-dimensional Hilbert space and generate transformations in the sense of Lie algebras. We can build several quaternions of this type using Pauli matrices and thus find all matrices that perform Wick-rotations on them. For instance,

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & +1 \\ +1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \begin{pmatrix} +\mathbb{1}_2 \\ +i\sigma_1 \\ +j\sigma_1 \\ +k\sigma_3 \end{pmatrix} = \begin{pmatrix} +\imath\mathbf{i}_2 \\ -\sigma_1 \\ -\sigma_3 \\ -\sigma_1 \end{pmatrix}. \quad (10)$$

Clearly however, these transformations may be non-trivial, depending on the representation employed. A Wick-rotation in the broad sense is the transformation of a real component into an imaginary one (or *vice-versa*), not necessarily in unambiguous and direct way. The main advantage of the quaternionic marker base is that we can associate it with any magnitude we wish to analyze spatially or temporally.

Wick-rotation turns spatial markers into temporal markers, and contrariwise. Under these circumstances, the previous temporal marker became spatial, restricting space freedom to a "filamentary" structure. What does that really mean? It is reasonable to think that each locus on the observer's filamentary trajectory constitutes its proper space and carries a temporal "trihedron" receiving signals of separate time events occurring at different locations. On the contrary, each moment in the observer's timeline constitutes its proper time and carries a space trihedron receiving signals from separate space events occurring at different times. All this has nothing to do with the accessibility of science fiction films, but it may indicate the possibility of free information transmission from the future to the past. The spatial filament could even be infinite, binding both entangled particles to any distance you want. Note that this has nothing to do with Newtonian-Euclidean view of simultaneity, for there is a proper time (as well as a proper space) of the observer, and the times and spaces relative to each observed event.

Despite everything I said, an overly anthropic universe has dominated our models of reality, leaving us confused by exotic phenomena such as quantum entanglement. The fact is: *a priori*, we may not realize something that does not happen entirely in our testable universe; to assimilate entanglement, a new configuration of spacetime coordinates must be shared by the entangled particles with a fifth connection-component embedded in one of the four-dimensional continuum components. This is precisely the situation in which we need to look for new ways of relating objects quite different from those we usually observe.

2.2 The matrices: complex open algebras

From the diversity of possible combinations, we may restrict the choices only to a set of matrices like matrix (10) (each of them multiplied by its transconjugated gives the unitary matrix) that elegantly represented those base transformations. For instance,

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & +1 \\ +1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \times$$

$$\begin{pmatrix} \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} \\ \begin{vmatrix} 0 & +1 \\ +1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \begin{vmatrix} -j & 0 \\ 0 & -j \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} -k & 0 \\ 0 & -k \end{vmatrix} & \mathbb{O} \end{pmatrix} = \mathbb{1}_4$$

These matrices form what I called a "complex open algebra" (the term "open algebra" was used for the freedom of choice of representations according to the intended physical-mathematical scope). They can also specify an additional invariant symmetry from multiplication operation; thus, it is possible to arbitrarily choose matrices that construct this symmetry. For example, the product of two matrices of a given complex open algebra will be a matrix whose nonzero entries are arranged in the same manner, with the same conjugate disposition. So,

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & +1 \\ +1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \times$$

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} 0 & +i \\ -i & 0 \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} -j & 0 \\ 0 & -j \end{vmatrix} \\ \begin{vmatrix} -j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} =$$

$$\begin{pmatrix} \mathbb{O} & \mathbb{O} & \begin{vmatrix} -i & 0 \\ 0 & +i \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +1 & 0 \\ 0 & +1 \end{vmatrix} \\ \begin{vmatrix} +i & 0 \\ 0 & -i \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \begin{vmatrix} +1 & 0 \\ 0 & +1 \end{vmatrix} & \mathbb{O} & \mathbb{O} \end{pmatrix},$$

where

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -1 \\ -1 & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} 0 & +i \\ -i & 0 \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} -j & 0 \\ 0 & -j \end{vmatrix} \\ \begin{vmatrix} -j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \begin{pmatrix} +\imath\mathbf{i}_2 \\ -\sigma_1 \\ -\sigma_3 \\ -\sigma_1 \end{pmatrix} =$$

$$\begin{pmatrix} +\mathbb{1}_2 \\ +i\sigma_1 \\ +j\sigma_1 \\ +k\sigma_3 \end{pmatrix}$$

is a Wick-rotation of

$$\begin{pmatrix} +\imath\mathbf{i}_2 \\ -\sigma_1 \\ -\sigma_3 \\ -\sigma_1 \end{pmatrix}.$$

In this case, it would be required that all product-matrices of the particular complex open algebra would have the form

$$\begin{pmatrix} 0 & 0 & m & 0 \\ 0 & 0 & 0 & n \\ m^{\dagger} & 0 & 0 & 0 \\ 0 & n & 0 & 0 \end{pmatrix}.$$

2.3 *Another dimension?*

Of course, if we think of space (or time) reduced to a filament it will be natural to deduce that there may be many independent, but somehow connected, filaments. To assume by the conventional way a fifth dimension that answers by such connection would lead us back to the old question of why we do not perceive it. In addition, we would add an unnecessary matrix complication. It seems more elegant to suppose a hidden component[5] embedded in the fourth dimension and signed by an imaginary unit distinct from the others, defined as $\varepsilon = \sqrt[4]{-1}$. We do not perceive it because it is part of the fourth dimension, and because it is, by definition, null under Wick-rotation. In fact, the component associated with the fourth dimension, that is, the "bridge" between the infinite filaments of time or space, expresses what really constitutes the edifice of the continuum: four-dimensional slices that stand out from a "fifth direction" that is neither time nor space. And, more precisely, the qualitative difference between space and time, which is imposed on us by perception, does not belong to the objective world, as Weil has pointed out [16].

That fifth direction manifests, by definition, the interesting property of being null under Wick-rotations and "sluepotent". An sluepotent operation is one where a quantity a is such that $aa = i$. Thus,

1. $i\varepsilon = j\varepsilon = k\varepsilon = 0;$ (11)
2. $\varepsilon\varepsilon = i.$ (12)

Given this new perspective, let's look at the matrix structure of the representation outlined above. I must define the following matrices,

$$\mathrm{E}_1 = \begin{bmatrix} \sqrt[4]{-1} & 0 \\ 0 & \sqrt[4]{-1} \end{bmatrix} = \begin{bmatrix} \varepsilon & 0 \\ 0 & \varepsilon \end{bmatrix};$$

$$\mathrm{E}_2 = \begin{bmatrix} 0 & -\sqrt[4]{-1} \\ -\sqrt[4]{-1} & 0 \end{bmatrix} = \begin{bmatrix} 0 & -\varepsilon \\ -\varepsilon & 0 \end{bmatrix};$$

$$\mathrm{E}_3 = \begin{bmatrix} 0 & -\sqrt[4]{-1} \\ \sqrt[4]{-1} & 0 \end{bmatrix} = \begin{bmatrix} 0 & -\varepsilon \\ \varepsilon & 0 \end{bmatrix};$$

$$\mathrm{E}_4 = \begin{bmatrix} \sqrt[4]{-1} & 0 \\ 0 & -\sqrt[4]{-1} \end{bmatrix} = \begin{bmatrix} \varepsilon & 0 \\ 0 & -\varepsilon \end{bmatrix}.$$

From the new definitions and with the bridge represented in the first quaternion component, it is possible to write the transformation

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -i \\ -i & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -\varepsilon \\ \varepsilon & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \begin{pmatrix} (\mathbb{1}_2, \mathrm{E}_1) \\ +i\sigma_1 \\ +j\sigma_1 \\ +k\sigma_3 \end{pmatrix} = \begin{pmatrix} +\mathbb{1}_2 \\ -\sigma_1 \\ -\sigma_3 \\ (\sigma_2, \mathrm{E}_3) \end{pmatrix}, \tag{13}$$

where the new quaternion includes the bridge in the last component.

We note that the inversion of this transformation is given by

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -1-\varepsilon \\ -1-\varepsilon & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} 0 & +i \\ -i & 0 \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} -k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} +k & 0 \\ 0 & -k \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \times \begin{pmatrix} +\mathbb{1}_2 \\ -\sigma_1 \\ -\sigma_3 \\ (\sigma_2, \mathrm{E}_3) \end{pmatrix} = \begin{pmatrix} (\mathbb{1}_2, \mathrm{E}_1) \\ +i\sigma_1 \\ +j\sigma_1 \\ +k\sigma_3 \end{pmatrix}. \tag{14}$$

We can go on and complete the calculation doing the product of the two matrices

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -i \\ -i & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} +j & 0 \\ 0 & +j \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} +k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} 0 & -\varepsilon \\ \varepsilon & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} \times$$

[5] The discussion of transempirical or hidden features in the structure of the universe is not new. Bohm's conjecture about hidden variables dates from the 1950s [1]. Nevertheless, the situation I am discussing does not have exactly the same epistemological nature. In Bohm's model, the well-defined momentum and position variables of a particle are called its supplementary, or hidden, variables with respect to quantum theory; they have simultaneous existence, but they do not explicitly appear in the process except in the form of a certain quantum potential. In my theory, by contrast, there is a hidden supplementary dimension which has, yet, no classical root or any natural correspondence with previously known quantities that would now be simply "unseen" due to new theoretical dispositions and formal arrangements.

$$\begin{pmatrix} \mathbb{O} & \begin{vmatrix} 0 & -1-\varepsilon \\ -1-\varepsilon & 0 \end{vmatrix} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \begin{vmatrix} 0 & +i \\ -i & 0 \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} -k & 0 \\ 0 & +k \end{vmatrix} \\ \begin{vmatrix} +k & 0 \\ 0 & -k \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \end{pmatrix} =$$

$$\begin{pmatrix} \mathbb{O} & \mathbb{O} & \begin{vmatrix} -1 & 0 \\ 0 & +1 \end{vmatrix} & \mathbb{O} \\ \mathbb{O} & \mathbb{O} & \mathbb{O} & \begin{vmatrix} -i & 0 \\ 0 & +i \end{vmatrix} \\ \begin{vmatrix} -1 & 0 \\ 0 & +1 \end{vmatrix} & \mathbb{O} & \mathbb{O} & \mathbb{O} \\ \mathbb{O} & \begin{vmatrix} +(\varepsilon+i) & 0 \\ 0 & -(\varepsilon+i) \end{vmatrix} & \mathbb{O} & \mathbb{O} \end{pmatrix} . \quad (15)$$

The product of this matrix by its transpose conjugate provides

$$\begin{pmatrix} 0 & 0 & -\sigma_3 & 0 \\ 0 & 0 & 0 & -i\sigma_3 \\ -\sigma_3 & 0 & 0 & 0 \\ 0 & (i\sigma_3, E_4) & 0 & 0 \end{pmatrix} \times$$

$$\begin{pmatrix} 0 & 0 & -\sigma_3 & 0 \\ 0 & 0 & 0 & (-i\sigma_3, E_4) \\ -\sigma_3 & 0 & 0 & 0 \\ 0 & i\sigma_3 & 0 & 0 \end{pmatrix} =$$

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & \tilde{\mathrm{U}} \end{pmatrix}, \tilde{\mathrm{U}} = 1 + i.$$

The choices and the sequence of operations were such that we came to the unitary matrix of the theory, the "Ũ-matrix", that is, a matrix with the last diagonal entry equal to the complex unit, consequence of the fifth dimension embedded in the fourth.

It is not purpose of this essay to exhaust all options that would lead to similar results, but merely to demonstrate one consistent result. Since I am dealing only with the geometric framework of the representation, ongoing studies will further illustrate the usefulness of the quaternionic basis discussed with applications.

PART: FINAL REMARKS

3 Times of a new time

Time really fascinates. As a physicist, I try to ease mental tension by having fun with good sci-fi movies, especially those whose scripts deal with the pitfalls of time. Indeed, they can often provoke interesting perspectives. Recently, my favorite series, Star Treck Discovery, has reaffirmed this truth to me. Fictional extrapolations apart, episode 12 of season 2 shows a Klingon monastery on the remote planet Boreth; a monk, guardian of the "time crystals", voiced a remarkable thought: "when the future becomes the past, the present shall be released". If the subject of the film were the quantum entanglement, no verbal construct could be better to synthesize the essence of the phenomenon.

Tied to a linear time and to a way of thinking about separate things, we can hardly decipher the deepest puzzles of nature. The idea of a three-dimensional time from the perfect symmetry between space and time allows us to think of different ways of organizing and describing the relationships between objects and sets of objects. If we accept this possibility, we will be better able to understand quantum entanglement and other phenomena not yet fully elucidated.

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Adição de Fibras de Celulose (Papel *Kraft*) no Concreto
Verificação da Absorção por Capilaridade

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Resumo

Introdução: Atualmente, ocorre no Brasil destinação inadequada de materiais da construção civil, fato que acarreta impactos negativos ao meio ambiente e, consequentemente, preocupação com a busca de métodos viáveis e sustentáveis de reciclagem e reintegração desses materiais no ciclo produtivo, bem como a verificação da influência desses materiais quando reintegrados à construção civil. **Objetivo:** Apresentar um possível método de reciclagem de fibras de papel *kraft* e analisar, através de pesquisas e testes, sua viabilidade na construção civil, considerando aspectos como a absorção de água por capilaridade. **Materiais e Métodos:** O estudo foi realizado com levantamentos bibliográficos e, em seguida, com testes laboratoriais para analisar a influência da adição de fibras de papel *Kraft* no concreto, verificando a absorção por capilaridade. **Resultados:** De acordo com os testes e os processos empregados, a reciclagem de fibras de papel *kraft* é viável, pois sua adição ao concreto não altera abruptamente as propriedades do material e atende aos padrões de umidade. **Conclusão:** Concluiu-se que a adição de fibras de papel *kraft* no concreto pode reduzir o desperdício na construção civil, trazendo benefícios ao meio ambiente e sendo totalmente sustentável. Concluiu-se também que as fibras aumentam a capacidade de absorção do concreto; por esse motivo, o valor ideal adotado para a adição de fibras é de 0,5% g, característica que garantiu melhor resistência mecânica e menor coeficiente de absorção por capilaridade.
Palavras-Chave: Construção Civil; Reciclagem; Fibra de Papel *Kraft*; Celulose; Absorção; Umidade

Abstract

Introduction: Currently, we have in Brazil the inadequate disposal of waste construction materials, bringing negative impacts to the environment and consequently the concern to the search of viable and sustainable methods for recycling and reintegration of these materials in the production cycle, as well as the verification of the influence of these materials when reintegrated to civil construction. **Objective**: To present a possible method of recycling kraft paper fibers and to analyze, through research and testing, their viability in civil construction, considering aspects such as water absorption by capillarity. **Materials and Methods:** The study was conducted with bibliographic surveys and then with laboratory tests to analyze the influence of the addition of kraft paper fibers in concrete checking the absorption by capillarity. **Results:** According to testing and processes, kraft paper fibers recycling is feasible in that its addition to concrete does not abruptly change material properties and meets moisture standards. **Conclusion:** It is concluded that the recycling and addition of kraft paper fibers in concrete can be applied to reduce construction waste, bringing benefits to the environment and being fully sustainable. It is also concluded that the fibers increase the absorption capacity of concrete; for this reason, the ideal value adopted for fibers to be added is 0.5% g, a trait that ensured better mechanical strength and a lower coefficient of absorption by capillarity.
Keywords: Civil Construction; Recycling; Kraft Paper Fiber; Cellulose; Absorption; Humidity

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1- Introdução

A construção civil é um dos setores de grande importância para a economia brasileira; está sempre em movimento e em produção, e sempre à procura de avanços tecnológicos que visam contribuir para a utilização de métodos não destrutivos (PEREIRA, 2018).

A indústria da construção civil está entre as maiores causadoras de impactos ambientais, caracterizados tanto pela utilização de recursos naturais quanto pela alta geração de resíduos. De acordo com dados do SINDUSCON (2016), grande parte dos resíduos existentes no Brasil são provenientes de construções e demolições.

A resolução nº 307 do CONAMA, que trata da gestão dos resíduos da construção civil, define e classifica os tipos de rejeitos de acordo com suas características. Além disso, prioriza a não geração desses e dispõe sobre as etapas de gerenciamento, incluindo o adequado processo de descarte para cada classe.

O descarte inadequado de resíduos da construção e da demolição (RCD) é um problema que deve ser enfrentado. A reutilização e a reciclagem dos materiais são processos que ajudariam a reduzir os impactos negativos, favorecendo o meio ambiente (ALVES, 2016).

De acordo com dados do SNIC, de maio de 2018 a abril de 2019 as vendas acumuladas de cimento totalizaram 53 milhões de toneladas, sendo que o cimento ensacado representa 66% das vendas no Brasil. A grande quantidade de material produzido e posteriormente descartado de modo inadequado traz a preocupação em desenvolver meios viáveis e sustentáveis para a reintegração desses materiais no ciclo produtivo.

Os sacos de cimento são produzidos com papel *kraft* multifoliado. Segundo Buson (2009), este apresenta alta resistência, sendo submetido a padrões rígidos exigidos pelos fabricantes e consumidores de cimento. Além disso, as especificações técnicas de produção das embalagens exigem uma celulose produzida pelo processo de sulfato, de alta resistência e de fibra longa, que é geralmente empregada pura (proveniente de celulose de madeira ou de bambu), garantindo à fibra excelentes propriedades físicas e mecânicas.

De acordo com tais características, e vizando principalmente a reutilização de materiais, a presente pesquisa compreenderá a adição de fibras de celulose recicladas do papel *kraft* no concreto. Segundo Alves (2016), o teor máximo de fibra a ser adicionada é de 1%; quanto maior a quantidade de fibras, menor a resistência do concreto. Dentre os valores analisados, destaca-se o teor de 0,5%, com o qual se obtém melhores resultados, atendendo aos valores e características exigidos por norma (BUSON, 2009).

A fibra *kraft* propicia uma mudança no compósito que o torna mais absorvente (SANTOS e CARVALHO, 2011). A avaliação da absorção e da umidade do concreto com fibras é de suma importância, pois, a umidade é um dos maiores problemas quando se fala em patologias das estruturas.

Portanto, será avaliada a penetração de água por absorção capilar do concreto produzido com e sem fibras, para que possam ser confrontados ambos os materiais em termos dos seus comportamentos. Para tanto, a NBR 9779/2012 detalha os procedimentos a serem seguidos e os cálculos a serem efetuados.

Materiais e Métodos

O papel *kraft* empregado nas embalagens de cimento é proveniente de polpa química de fibra longa de celulose obtida da madeira; essas fibras podem ser produzidas de maneiras diferentes, por meio de processos mecânicos e processos químicos (PEREIRA, 2018).

No processo de reciclagem das fibras de celulose foram necessários sacos de cimento vazios, água, agitador, peneira, triturador e local para que as fibras possam ser secadas naturalmente.

O processo começa com a limpeza dos sacos de cimento, primeiro retirando o resíduo de cimento seco ainda presente nas embalagens. Nessa pesquisa foram usadas 6 embalagens de cimento, e retirados 56,56g de cimento seco ainda presente nas embalagens, o que equivale a aproximadamente 0,025% de cimento desperdiçado para 6 sacos de cimento.

Em seguida, os sacos foram cortados, higienizados e deixados de molho. Foram agitados até que se transformassem em polpa de celulose, retirado o excesso de água, e, posteriormente, triturados a fim de se obterem as fibras de celulose. Logo em seguida, essas fibras foram dispostas para secagem. Neste estudo, foi verificado que, no primeiro procedimento de obtenção da polpa de celulose, permaneceram pedaços de papel *kraft* inteiros, o que acarretou a necessidade de repetição do processo.

O processo de agitação e a sua duração variam de acordo com o equipamento. O papel deve ser agitado pelo tempo necessário para a formação da polpa. A água usada pode ser reutilizada várias vezes, evitando assim desperdício.

O procedimento de reciclagem é simples, baseado apenas em processos mecânicos, pouca energia e água. Após a agitação dos sacos de cimento para obtenção da polpa de celulose, aplica-se o processo da retirada do excesso de água da polpa para que seja possível a trituração e obtenção das fibras *kraft* (figura 1).

Figura 1 – Processo de retirado do excesso de água da polpa.

Obtenção das fibras

No processo de obtenção das fibras foram utilizados seis sacos de cimento, agitados por aproximadamente uma hora e trinta minutos e secados por uma semana, sendo por fim triturados. Nas figuras 2 e 3 é possível observar respectivamente a polpa de celulose após a retirada do excesso de água e as fibras já trituradas e prontas para serem utilizadas.

Figura 2 – Polpas de fibras de celulose.

Figura 3 – Fibras de papel *kraft.*

Durante o processo de produção da polpa, foi possível notar a resistência das embalagens de *kraft*, fato que obrigou por repetidas vezes a parada da agitação para diminuição do tamanho dos pedaços de papel.

Celulose

A celulose é um polissacarídeo, componente estrutural primário das plantas e base para a fabricação de papeis. É um dos compostos que constituem a madeira, cerca de 50%; suas moléculas, agrupadas pela lignina, configuram feixes de fibras formadores das células vegetais (CMPC, 2019).

As fibras celulósicas podem ser encontradas com diferentes características, o que influencia diretamente o seu comportamento. A celulose de fibra longa, foco desse estudo, possui grande capacidade de resistência (principalmente à tração), de absorção de água, e porosidade significativa (KLABIN, 2019).

As fibras naturais são diretamente afetadas pelo grau de alcalinidade do meio (SAVASTANO, 2000). Logo, a fibra tende a se degradar quando envolvida com o cimento, o que acarreta diminuição da sua vida útil.

Corpos de prova

Para que fosse possível a análise da umidade sob influência das fibras no concreto, foram moldados corpos de provas (doravante CP) com cimento CP V ARI, brita 0 e areia média. Foi aplicado aditivo plastificante porque esse reduz a quantidade de água, mantendo o *slump*; ele não diminui a resistência, mas não foi adicionado em todos os CP. A moldagem teve lugar de acordo com a NBR 5738/2015, que estabelece critérios como as dimensões dos CP, os processos para mistura dos materiais e moldagem, os processos para adensamento do concreto, além de dispor sobre o processo de cura, trazendo informações acerca do tempo, do armazenamento e do desmolde.

A fim de se analisar o comportamento da umidade no concreto com adição das fibras de celulose, foram moldados cinco CP. O CP1 foi produzido com 0,5% de fibra em relação à massa de agregados; O CP2 com 1% de fibra e o CP3 com 1,5% de fibra. Todos receberam 1,5% de aditivo para facilitar o manuseio e o emprego das fibras no concreto, tendo em conta que o aditivo permite obter a mesma fluidez com menor quantidade de água.

Os outros CP foram moldados de forma convencional para que seus desempenhos pudessem ser confrontados com os dos demais contendo fibras. Portanto, o CP4 foi produzido sem adição de fibra e sem aditivo; o último, CP5, sem adição de fibra e com 1,5% de aditivo. A figura 4 ilustra os CP submetidos à análise.

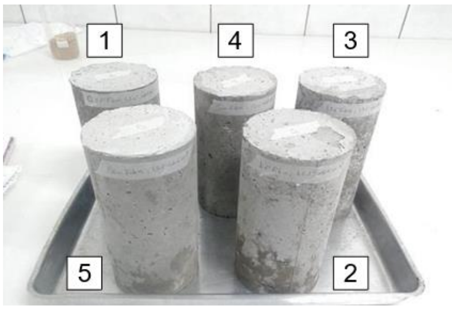

Figura 4 – Corpos de prova.

Umidade e absorção por capilaridade:

A umidade é um dos maiores problemas quando se fala em patologias, afetando diretamente a eficiência das estruturas. Suas causas são normalmente decorrentes de fenômenos naturais como chuvas, umidade do ar, do solo e entre outros (Santana e Aleixo, 2017). De acordo com Perez (1986), a umidade pode ser proveniente da própria construção, de infiltração ou de condensação; pode ainda ser acidental e ascensional.

Ascensional é o termo usado para definir a umidade causada pela água que penetra o concreto por capilaridade (transporte da água no estado líquido) (PEREZ, 1996). Segundo Pinto (1998), capilaridade é a propriedade de um material em promover a sucção de água quando em contato com ela, dependendo de vários fatores. Pode ser definida também como o fluxo vertical de água.

As patologias causadas no concreto devido à umidade trazem desconforto e podem variar desde problemas simples à problemas mais complexos que afetam a estrutura e o seu funcionamento. Segundo Perez (1985), a umidade nas edificações representa um dos problemas mais difíceis de serem corrigidos no âmbito da construção civil, assim como a lixiviação do concreto, problema causado pelo contato da estrutura com a água, e que se caracteriza pela dissolução e pela remoção do hidróxido de cálcio formado no processo de hidratação do cimento. Outro problema causado pela umidade é a despassivação das armaduras concomitante à reação de corrosão do aço.

A NBR 9779/2012 determina o ensaio e o cálculo para a absorção de água por capilaridade. Os ensaios foram realizados seguindo a norma e foram avaliados posteriormente.

Tabela 1 – Constância de massa para CP1.

Corpo de Prova 1	Peso (g)
tempo 0 (massa seca)	3149,70
3hrs	3163,94
6hrs	3168,98
24hrs	3168,06
48hrs	3172,57
72hrs (massa saturada)	3168,79

É importante conhecer a interação da água com todos os materiais envolvidos, sendo ela matéria prima nas obras, estando presente em todas as fases da construção e durante toda a vida útil da estrutura.

Absorção por capilaridade

Para se obter o coeficiente de absorção por capilaridade utilizou-se a equação (1) dada na NBR 9779/2012, que o caracteriza como a razão da diferença entre as massas saturadas e as secas em estufa sobre a área de seção transversal.

$$C = \frac{Msat - Ms}{S}, \qquad (1)$$

onde: *C* = coeficiente de absorção de água por capilaridade (g/cm²), *Msat* = massa saturada (g), *Ms* = massa seca (g), *S* = área da seção transversal (cm²).

Os CP secos ao ar foram pesados e em seguida colocados em estufa para chegarem à constância de massa. Foram resfriados e imergidos em água até +/- 5mm da sua base inferior. Em seguida, foram registradas as massas com 3, 24, 48 e 72 horas. As dimensões dos moldes dos CP são de 10x20 cm de acordo com a figura 5.

Figura 5 – CP imergidos na água

Resultados

A fim de se verificar o comportamento da umidade dos CP após a adição das fibras de celulose, as tabelas de 1 a 5 apresentam suas respectivas massas para registro do coeficiente de absorção.

Na tabela 1 é possível verificar uma variação de 19,09g entre massa seca e massa saturada do CP1 após 72 horas. Na tabela 2 verifica-se a diferença de 23,85g entre massa seca e massa saturada do CP2.

Tabela 2 – Constância de massa para CP2.

Corpo de Prova 2	Peso (g)
tempo 0 (massa seca)	3068,08
3hrs	3082,07
6hrs	3082,84
24hrs	3089,41
48hrs	3093,94
72hrs (massa saturada)	3091,93

O CP3 demonstra uma diferença de massa de 19,07g (tabela 3).

Tabela 3 – Constância de massa para CP3.

Corpo de Prova 3	Peso (g)
tempo 0 (massa seca)	3033,52
3hrs	3047,92
6hrs	3047,63
24hrs	3051,97
48hrs	3055,61
72hrs (massa saturada)	3052,59

O CP4 foi moldado de forma usual para servir como referencial comparativo, portanto sem fibras e sem aditivo, apresentando diferença de massa igual a 21,07g (tabela 4).

Tabela 4 – Constância de massa para CP4.

Corpo de Prova 4	Peso (g)
tempo 0 (massa seca)	3211,69
3hrs	3226,29
6hrs	3226,35
24hrs	3231,80
48hrs	3235,28
72hrs (massa saturada)	3232,76

A tabela 5 exibe uma diferença de 15,6g para o CP5.

Tabela 5 – Constância de massa para CP5.

Corpo de Prova 5	Peso (g)
tempo 0 (massa seca)	3274,65
3hrs	3287,22
6hrs	3286,84
24hrs	3290,28
48hrs	3293,94
72hrs (massa saturada)	3290,25

Os coeficientes de absorção de água para cada corpo de prova, calculado de acordo com a equação (1), são apresentados na tabela 6, onde a diferença de massa entre os corpos de prova é de 0,105g entre a maior e a menor.

Tabela 6 – Coeficiente de absorção por capilaridade.

Coeficiente de absorção por capilaridade (g/cm²)	
CP1 – 0,5% Fibra + 1,5% Aditivo	0,243
CP2 – 1% Fibra + 1,5% Aditivo	0,304
CP3 – 1,5% Fibra + 1,5% Aditivo	0,243
CP4 – 0% Fibra + 0% Aditivo	0,268
CP5 – 0% Fibra + 1,5% Aditivo	0,199

Discussão

A diferença de massa entre o CP1 e CP2 foi de 0,061g, e pode estar relacionada ao volume de fibra de celulose adicionado. É sabido que as fibras são absorventes, mais ainda se não tratadas quimicamente. No CP2, obteve-se o maior coeficiente de absorção (estudos realizados mostram que as fibras podem ter aumento de massa em até 50%). Já o CP3 apresentou massa igual ao CP1, embora a diferença entre volumes de fibras seja de 1% a mais para o CP3; este fato pode estar associado à adição de ativo plastificante, pois esse tem a função de reduzir ou manter a quantidade de água usada no concreto, preservando suas características. Outro fator importante no processo é a homogeneização do concreto, pois, quanto mais homogêneo o concreto, menor a sua porosidade, o que consequentemente afeta os resultados.

O CP4 apresentou um volume de massa apreciável comparado aos outros CP, porém, como declarado anteriormente, sem adição de fibras e sem aditivo; este fato pode estar relacionado à necessidade de água do próprio cimento para o processo de cura, à porosidade do concreto e à falta de homogeneização, que influenciam diretamente a umidade por capilaridade.

Para o CP5 foi possível verificar que o aditivo influenciou diretamente a relação água/cimento do concreto, pois permitiu reduzir a quantidade de água acrescentada sem modificar a consistência do concreto. O aditivo também ajudou a homogeneizar as partículas de cimento, liberando a água que fica presa nos grãos por meio da reação de repulsão entre eles provocada por cargas elétricas. De maneira geral, a diferença de massa está relacionada à capacidade de absorção de água dos corpos de prova em virtude do acréscimo de fibra, pois a celulose de fibra longa possui grande capacidade de absorção devido a sua alta porosidade. Portanto, o aditivo plastificante é adicionado ao concreto para obter maior fluidez com menor quantidade de água, aumentando a plasticidade, propriedade que o concreto possui definida pela facilidade com que o mesmo pode ser moldado sem se romper.

Devido ao processo de moldagem manual dos CP, pode ter ocorrido falha na mistura, no adensamento e em outros critérios que possivelmente influenciaram os resultados. Os processos automatizados ou industriais melhoram a produção de concreto quanto à homogeneização, ao adensamento e à mistura. Ainda, durante a reciclagem das fibras, podem ter permanecido alguns fragmentos de papel. De toda sorte, mesmo que tais fatos tenham interferido com os resultados, estes se mostraram consistentes com as premissas básicas adotadas na literatura técnica.

As indústrias que trabalham com as fibras naturais de celulose costumam aplicar alguns tratamentos químicos a fim de melhorar características como aderência da fibra, redução da capacidade de absorção e durabilidade das fibras em meios alcalinos. Alguns desses tratamentos são a acetilação, a hornificação, a lavagem com soluções alcalinas, a impregnação de polímeros e os tratamentos térmicos. Esses tratamentos têm o objetivo de melhorar o desempenho das fibras nas matrizes cimentícias.

Conclusão

Diante do exposto nessa pesquisa, concluiu-se que a adição da fibra *kraft* ao concreto, apesar dos efeitos negativos da maior absorção de água, pode ser empregada para reduzir os resíduos da construção civil, além do que, a reciclagem das fibras traz benefícios para o meio ambiente, não requerendo grande quantidade de recursos e não necessitando de processos químicos sofisticados.

É importante frisar que os CP não foram ensaiados quanto às resistências mecânicas. Entretanto, ao analisar os dados de outras pesquisas, concluiu-se que o excesso de fibras implicaria em menor resistência, não atendendo aos padrões mínimos. Com essa ressalva, a adição mínima de 0,5% de fibra foi considerada ideal, pois, de acordo com os resultados, o CP1 mostrou-se mais impermeável que os demais, evitando possíveis problemas decorrentes da umidade.

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Guanabara Bay

Proposals for a Territory of Exclusion Born from Paradise — Part II, For a Macro-Engineering Covenant

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Abstract: Previously, we discussed the prevailing regional eco-cultural situation of Guanabara Bay (GB), characterizing it as a true Exclusion Territory under the action of obviously stressful degenerative anthropogenic phenomena, which have dramatically affected all persons living in its vicinity. Having suggested actions that could mitigate the damages already caused to the environment and the population, this detailed article completes the general proposal presented in PART I of our research on the possible creation of a pipeline system transferring pressurized oceanic seawater extracted from the South Atlantic Ocean to the vast shallow interior of upper GB, presenting a viable alternative that can become useful to other similarly distressed nations in Earth's biosphere. In summary, because of our confidence in the effectiveness of geographically large-scale ambitious megaproject plans for the orderly and sustainably use and enjoyment of both public and private urban spaces, our strongly suggestive study constitutes an aspirational Macro-Imagineering prospect for the recovery of the remaining mangrove forests, famed beaches and fishing activity within GB, rescuing and enhancing a potential quality of life for GB's permanent bayfront human population.

Key words: Guanabara Bay, human quality of life, seawater pipeline system.

Resumo: Anteriormente, discutimos a situação ecocultural vigente na Baía de Guanabara (BG), caracterizando-a como um verdadeiro Território de Exclusão sob a ação de fenômenos antrópicos degenerativos que afetam dramaticamente todas as pessoas que vivem em sua vizinhança. Tendo sugerido ações que poderiam mitigar os danos já causados ao meio ambiente e à população, este artigo detalha e completa a proposta geral apresentada na PARTE I de nossa pesquisa sobre a possível criação de um sistema de dutos transferindo água de mar aberto pressurizada, extraída do Atlântico Sul, para o interior raso da BG, apresentando uma alternativa viável que pode se tornar útil a outras nações igualmente afetadas pela degradação ambiental de suas regiões costeiras. Em suma, devido à nossa crença na eficácia de megaprojetos para o uso e o aproveitamento sustentável de espaços urbanos públicos e privados, o presente estudo, altamente sugestivo, constitui uma perspectiva macro-imaginativa para a recuperação dos manguezais, das praias famosas e das atividades de pesca na BG, resgatando e aumentando a qualidade de vida da população do seu entorno.

Palavras-chave: Baía de Guanabara, qualidade de vida, sistema de transferência de águas oceânicas.

1. Introduction

One of the most surprising and inexplicable facts is the absence of wise and timely investments in necessary environmental recovery, when it is known that classical physics offers sufficient theoretical and experimental evidence to account for most of the environmental problems [1-4], and that humanity's survival for a little more Geologic Time in Earth will depend on such investments. More than that, people go hungry by millions, suffering from diseases caused by disgustingly poor water quality; despite this, it seems few anywhere are thinking seriously of large-scale application of technically simple and low-cost fluid pumping devices that hold the possibility to extinguish the daily existential agonies of bayfront-sited people worldwide. Our Earth is a marine habitat, especially for residents of its Southern Hemisphere [5]! In fact, on the basis of the ratio of maximum length of the major bay axis (~30 km) to the entrance width (~1.5 km) — in this particular instance, about 20 — GB qualifies oceanographically as an **enclosed sea** characterized by markedly inhibited tidal flushing, a non-oceanic

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sea-wave climate, variable seawater salinity and temperature vertical and horizontal structure, a marginal sedimentary basin as well as a pollutant trap, with a unique and distinctive aquatic ecosystem different from the South Atlantic Ocean adjacent. This enclosed sea is a relatively quiescent seascape, the external seawater flow is micro-tidal and the exchange between GB and the ocean is the most important hydrodynamical mechanism for the transport and dispersion of pollutants as well as substances such as nutrients and deposited sediments. Wherever pollutants are retained in the GB for some time, entrapment of the effluvial of GB's urban syndrome streams is the essential cause [6]. The bay-bottom is festooned with macroscopic trash. Tidal measurements done by Sanches Dorta during AD 1781 commenced near the entrance to GB close to Rio de Janeiro. Interfering modern landfills such as Fundão Island and the nearby International Airport have already slowed the normal seawater circulation of the western part of the GB. Because of the intentionally designed dimensions of its present-day main navigation channel, dug to accommodate the largest passing ocean-going vessels, the intensity of shipping and the maneuverability of the various types of vessels, it may be that alterations of the central navigation channel amplified the tide somewhat in the farthest reaches of uppermost GB. Certainly, rapid settlement of the steep slopes of the suburb of Niteroi City after the construction of the 8.8 km-long over-water section of the Rio-Niteroi Bridge intensified GB sedimentation after its completion during 1974 AD. Possibly the installed submarine sewage outfall situated in Jurujuba Sound deflects currents. In any case, we have foreseen that GB seawater movements post-device emplacement, may cause circulatory reactions as yet undiscerned by macro-imagineers. However, it was L.M. Mayr who anticipated the true possibility that very shallow areas of the GB can be flushed by a cleansing tide-induced seawter circulation [7]; we are first to appreciate that simple seawater pumping devices may in future improve on Nature's extant tidal regime at GB.

Guanabara Bay (GB) and its landscape surround—Nature's physiographic artwork already hugely modified by industrious and ecologically thoughtless humans—is hereby characterized a real-world territory of social exclusion, "aquacide" [8] as proposed by Roger H. Charlier (1921-2018) and even a possible 21st Century future place for "disaster tourism" [9] due to the increasingly visible pollution of its shallowest, most inland seawater mass. As a coastal body of seawater body belonging to a country with severe eco-social disfunctions, nowadays GB is a watery cast-off aquatic waste-bin of unwanted and unneeded anthropogenic exogenous substances. Since even Petrobras and others [10] may not care much about the actual poisoning of the Bay by petrochemical emissions, spills and dumped infrastructure castoffs, nevertheless we still maintain the hope that, as a foreign researcher as well as a proud citizen, we can together establish and disseminate to the immediate region's despoliation-beset human community a doable mechanical means to rehabilitate that coastal landform whose current state of near-term social abandonment affects, at different levels, about ten million human beings, both Brazilians and visitors.

Film-makers in Hollywood have "…been largely responsible for 'inventing' a specific image of Rio de Janeiro for world consumption" (11, page 52). 2017's ***Geostorm***, at time 1.06.23 shows Rio de Janeiro beachgoers dressed as 1962's "The Girl from Ipanema" (AKA, Helo Pinheiro) instantly frozen to death because of errant beamed-energy operations of a sabotaged world weather control satellite command-post. If instead we presume that GB is truly a reflection of prevailing local human consciousness [12], set to a modern-day song music superseding the still popular *bossa nova* jazz, then some substitute must please the cariocas and others; it cannot be virtual hang-gliding over Rio de Janeiro backgrounded by a nearly 60 year-old enjoyable tune [13]! Claude Levi-Strauss

(1908-2009) unkindly epitomized the narrow GB entrance/exit channel as an ugly toothless human mouth; shamefully, today in the 21st Century period of our world's ocean losing "breath" due to basin-scale hypoxia, he might perhaps have added that the GB has aquatic halitosis [bad-breath] in the form of polluted and contaminated seawater during its ebb-tide "exhalations" (14)!

Whilst there is always curative hopes, certainly there is no single technological GB recovery solution solving all eco-social ills at once. Political will, education and waste management in a broad context of environmental governance are among the main promoters of a sustainable project for the recovery of coastal or inland seawater bodies with effectiveness on the long term. It is high time to understand that we need to tenderly modify our Earth-world's beloved regions such as GB .

2. The SIBEO Perspective

In the PART I of our work, we discussed the possibility of a macroproject comprised of pipelines transporting oceanic water, under pressure, to the stagnant shallow northernmost areas of the GB, creating a suitably piped artificial non-tidal seawater current capable of massive renewal of bay waters, thus promoting a more immediate bubbled oxygenation for the rehabilitation of fisheries. In search of similar experiences, fortuitously we have been offered an interesting proposal: the SIBEO initiative originating in Mexico.

The Wave Energy-Driven Seawater Pump (SIBEO in Spanish language) developed at the National University of Mexico (UNAM) may be an viable alternative to cleanse and improve the level of oxygenation in stagnated areas of GB by injecting open-ocean seawater abstracted from the surf-zone of the South Atlantic Ocean coastline, from Maricá to Itaipuaçú municipalities, allowing the unmolested passage of living marine organisms and reinvigorating the fisheries of bay-bordering municipalities (see Figure 2). Since SIBEO uses the available ever-renewing kinetic-energy of sea-waves, the operational monetary costs are thus very low. Certainly, financial affordability is a key requisite for any GB macro-project! Enhancing the hydrodynamics of GB seawater circulation, treating ghastly in-tributary organic sewage sent into GB with UV and heated carbon dioxide bubbles [15-16] and utilizing physical boom barriers/racking filters to preclude debris carelessly thrown into the contributory degraded rivers from entering an contaminating the GB might induce the once truly glorious mangrove forests to recover, a fostered rehabilitation result. Only ~30% of GB's pre-Columbian mangrove forest still exists [17], only 0.00694226% of the Earth-biosphere's estimated 1,152,361 km^2 total [18]. In face of similarities among the developing countries with respect to their environmental problems arising exclusively from overall inadequate water-seawater management, we think that efforts towards a Brazil-Mexico R&D technological co-operation would bring great benefits to both nations, as well as important gains in empirical Science advancement. A covenant on coastal waters governance for the countries of Latin-America could emerge from this international cooperation.

3. Physical Principles

The formalism for hydrodynamical modeling given by Czitrom *et al*. [19-20] came from Daniel Bernoulli's theorem, according to which, throughout any current line, the sum of the kinetic, piezometric and pressure energies is constant. In fact, this theorem is an extension of the principle of energy conservation. Czitrom and his co-workers begin with two non-linear time-differential equations coupled by an air-compression term (the forth term of both equations) to be submitted to numerical integration:

$$\left(\chi_1 + L_1\left(1+\varepsilon_1\right) + \frac{T}{\cos\theta}\right)\ddot{\chi}_1 + \frac{\dot{\chi}_1^2}{2} + \left(\frac{K_1}{2} + f_1\right)\chi_1\left|\chi_1\right|$$

$$+\frac{P_A-\rho g H}{\rho}\left[\left(1-\frac{A_1\chi_1-A_c\chi_2}{Vo}\right)^{-\gamma}-1\right] \quad (1)$$
$$+g\cos\theta\chi_1=W;$$

$$\left(\chi_2+L_2\left[\frac{A_c}{A_2}(1+\varepsilon_1)+\frac{L_c}{L_2}\right]\right)\ddot{\chi}_2+\frac{\dot{\chi}_2^2}{2}+\left(\frac{K_2}{2}+f_2\right)\chi_2|\chi_2|$$
$$+\frac{P_A-\rho g H}{\rho}\left[\left(1-\frac{A_1\chi_1-A_c\chi_2}{Vo}\right)^{-\gamma}-1\right] \quad (2)$$
$$+g\chi_2=0,$$

where:

1)- χ is the surface displacement in either duct with respect to the equilibrium level in compression chamber;
2)- Subscripts 1, 2 and *c* correspond, respectively, to resonant duct, exhaust duct and compression chamber;
3)- L_1 and L_2 are the resonant and exhaust lengths;
4)- Vo is the compression chamber volume;
5)- γ is the air compressibility;
6)- ρ is the seawater density;
7)- $g\cos\theta$ is the reduced gravity due to the inclination of resonant duct at compression chamber;
8)- W is the wave forcing computed by the resonant duct equation (1).
9)- A is the surface area.

Coupled, equations (1) and (2) incorporate Bernoulli's theorem by the second and fifth terms. Simulations were well performed by Czitrom *et al.* [1], with a model seawater pump driven by sea-waves of various spectra imitating the real world-ocean surface and testing the response of the system to each frequency component, so that there is no need to summarize this point. It is enough to note that, since in practice Bernoulli's theorem is not rigorously verified because of the presence of viscosity (friction) and formation of vortexes along the ducts, the coupling includes a non-linear third term that are not in Bernoulli's equation in order to account for friction and vortex losses, and radiation damping. This damping term includes the factor

$$\left(\frac{K_1}{2}+f_1\right)$$

also to allow energy extraction from the system. Lastly, the first term accounts for the inertia, and the restoring force on the oscillating system is assigned by the compression of the air-chamber combined to the gravitational force.

A brief refresher on Daniel Bernoulli's Theorem

To induce a certain current in a known and mapped stagnant area of the GB we must play by the rules established with Bernoulli's theorem. There is a tangential acceleration caused by a pressure difference in the direction of motion. Contrary to what one may mistakenly intuit, a lower pressure causes a higher velocity. A simple, reasoned deduction of Bernoulli's equation from Newton's law is sufficient to

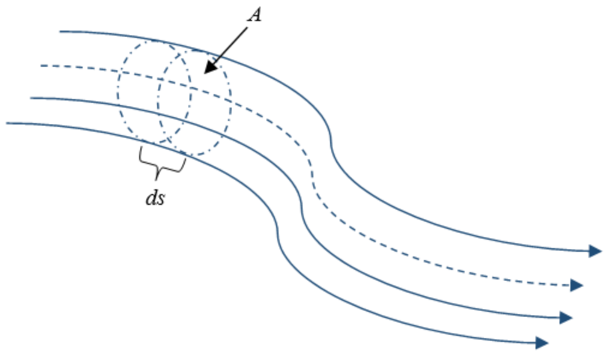

Figure 1 – A small segment of seawater flux.

clarify this fact. Now, let us take a very little Salami-slice piece of seawater held within an impermeable walled duct (Figure 1). This infinitely small mass element moves as a full conduit to which any mass variation is given by

$$dm=\rho A ds.$$

According to Newton's law, we may write

$$F = dma = \rho A ds \frac{dv}{dt}.$$

But, $F = AdP$, where P is the pressure, so that

$$A\frac{dP}{ds}\delta s = \rho A\delta s\frac{dv}{dt}.$$

Simplifying, we gain

$$\frac{dP}{ds} = \rho\frac{dv}{dt} = \rho\frac{dv}{ds}\frac{ds}{dt} = \rho v\frac{dv}{ds}.$$

Then,

$$dP = \rho v dv.$$

We can integrate this expression along the path z in the flux trajectory, such as

$$\int_z dP = \rho\int_z v dv,$$

so reaching the formal result of Daniel Bernoulli's theorem

$$P_{z_1} - P_{z_2} = \frac{\rho}{2}\left(v_{z_2}^2 - v_{z_1}^2\right),$$

an equality that clearly shows the relationship between increasing pressure and decreasing velocity. So, the GB SIBEO device must govern this relationship to gauge the seawater current mainly to refresh the internationally notorious most northern parts of Brazil's polluted upper GB. In fact, as described in Czitrom et al., the experimental pump implemented was just fully instrumented with seawater height-sensors and piezoelectric pressure sensors. Also, the device was prepared to measure the fluid's flow rate through the pump.

5. The *Organum Hydraulicum* in a Preliminary Approach

Organum Hydraulicum is the name we gave to the set of ducts that make up our macro-version of the SIBEO system, because the configuration of the discharge of sea water resembles the tubes of a church organ. The system was conceived for an average tidal volume of 268,000,000 cubic meters (m^3). The hourly flow needed to induce the anthropogenic tide, assuming 20% of the total value, would be 53,600,000 cubic meters per hour (m^3/h), which provides approximately 14,889 cubic meters per second (m^3/s).

The Bresse-Forchheimmer equation relates the diameter of the water duct in *m* (*D*) to the flow in m^3/s (*Q*) and the operating period of the system in hours per 24 hours (*x*), so that

$$D = C\sqrt{Q}\sqrt[4]{x},$$

where *C* is a constant[1]. Applying this formula for the calculation of the total pipe diameter[2], considering a realistic value of the constant *C* (= 0.75) and an operating period of 8 hours for every 24 hours, we obtain

$$D = 0.75\sqrt{14,889}\sqrt[4]{0.3333} \simeq 69.535m.$$

This is equivalent to 12 ducts of 5.8 *m* in diameter. Although the resonance compensation system directly influences the efficiency control, it is important to have a notion of the loss of charge per duct. Williams-Hazen's formula,

[1] The constant *C* is still controversial, seeking to reflect the relationship between investment cost and operating cost.

[2] Strictly speaking, the Bresse-Forchheimmer formula calculates the diameter of the rebound pipe in everyday cases of hydraulic projects. However, since in the project discussed there is no conventional suction pumping system and taking into account there will always be an elevation of the water from the sea level, we extrapolate the application of the formula, not ruling out possible further adjustments.

$$J = 10.641 \times c^{-1.852} \times D^{-4.87} \times Q^{1.852},$$

allows estimating the loss of load *J* in meters per meter (*m*/*m*), *c* being a constant that expresses characteristics of the internal surface of the duct (for concrete with a good finish, *c* = 130). Thus,

$$J = 10.641 \times 130^{-1.852} \times 5.8^{-4.87} \times 1,241^{1.852} \simeq$$

$$\simeq 0,133 m/m.$$

This would result in a loss of approximately 4 kilometers to be regulated by the compression chambers.

6. Technical Features

The most efficient geodetic trajectory for the resonant pipeline would cover approximately 30 kilometers, coming from the South Atlantic over the lagoon of Maricá, passing through the locality of Jardim Catarina and arriving at the northeast border of the GB in the immediate vicinity of the present ecological station (Figure 3). It is a place dominated by lowlands, interspersed by reliefs of low altitude. Except for some odd geological obstacle, most of the path chosen crosses a relatively free region. The route was designed taking into account the least possible urban impact and the lowest load losses. Also, the choice of the pipeline entrance zone was guided by the large supply of ocean waves in the area; it is well known the force of waves in the municipality of Maricá, which suffers occasional damage caused by the invasion of the sea. Thus, the great exposure of the coast of Maricá to the storm waves (swelling) of the southern quadrant makes this locale ideal for exploitation of the sea oscillation mechanical energy. An automatic system of floodgates in the vicinity of the lagoon of Maricá, comprising all 12 ducts, will allow the control of the influx of sea water according to the periods of tide. As in former SIBEO project, since the wave frequency changes in time, large variable volume compression chambers will be installed to adjust resonance.

Compared to the so-called "Great Man-made River", the ambitious Libyan irrigation network with more than 3,700 kilometers of pipelines, the *Organum Hydraulicum* will require a much smaller amount of prestressed concrete pipes, something around 360 kilometers, weighing between 70 and 90 tons each pipe unit. We expect that cranes of about 450 tons will be needed for the installation of concrete cylinders.

7. Final Remarks

It is not a question of sweeping the waste into the open sea. All measures to control dumping in GB should be concomitant with the implementation of the proposed anthropogenic sea dynamics. Environmental education certainly underlies these measures, in addition to a major effort to oversee the companies that currently pollute GB. The cost of implementing the project, although certainly high, is justified by the non-measurable social gain, as well as the medium-to long-term economic return of tourism and fishing activities**,** reminding that sanitation measures drastically reduce public health costs**.**

The beach system of the locality of Maricá is very dynamic, causing extreme events of storm and arrival of sea water beyond the coastline. All Maricá beaches are classified as exposed, which is why this project may include protection devices mainly on a critical point of the coast, the beach of Barra de Maricá, providing even the stabilization of waves for surfing. As can be seen, the gains are many, not only for the municipalities on the edge of GB, but for a whole region rich in tourism potential. It remains to be seen whether, behind the insidious corruption that punishes us for so many decades, there is true will and manhood for this important step towards social development.

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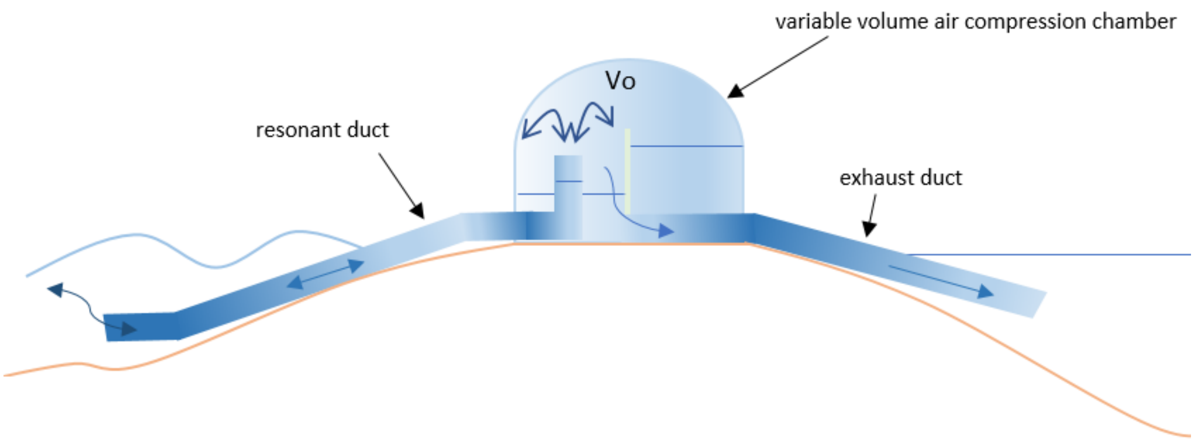

Figure 2 – The scheme of SIBEO engine.

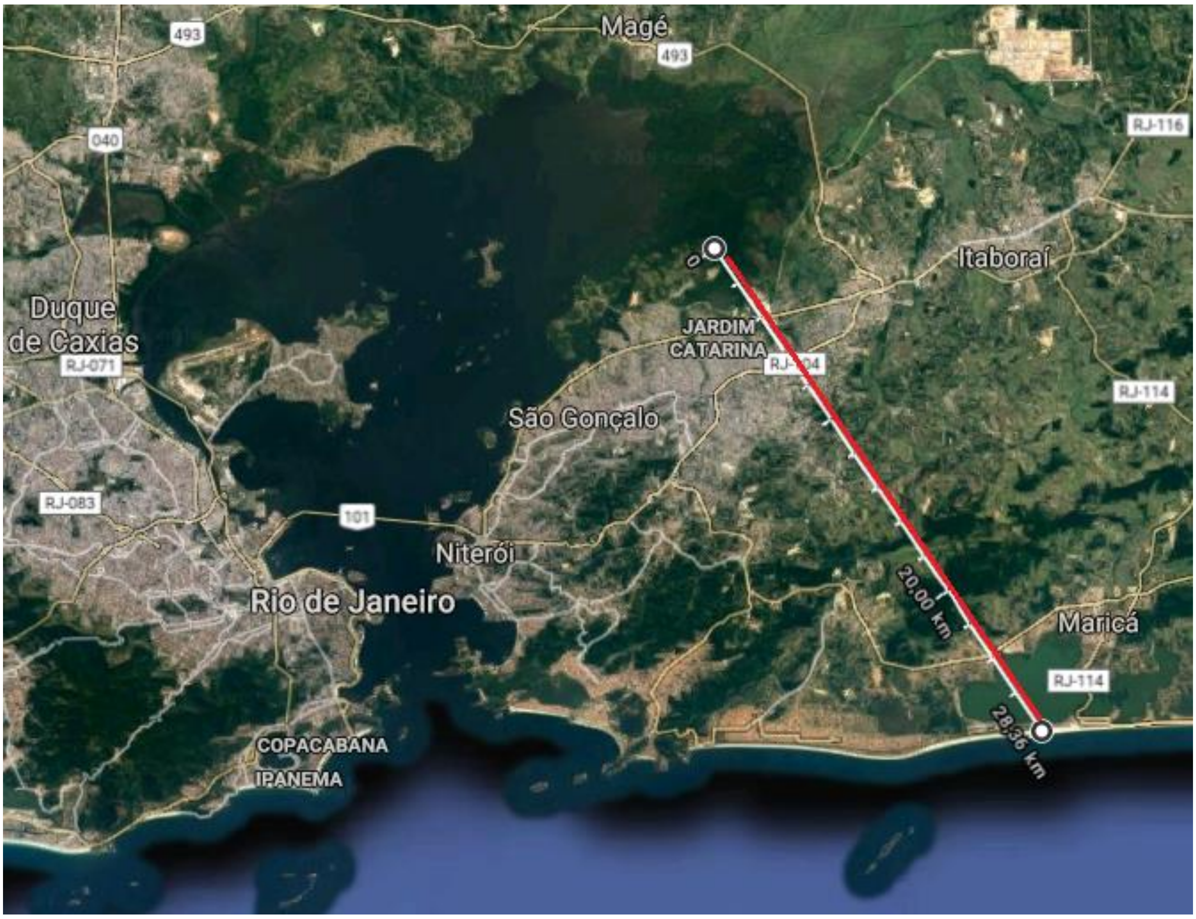

Figure 3 – The most efficient geodetic path.