Memory's Retention Time and Holography in Two Dimensions

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ABSTRACT- The holographic principle is extended to take in account a two-dimensional spherical universe. Applied to the frontier of the memory device, the working memory retention time is estimated. By considering the surface of the oxygen nucleus, the fusion temporal threshold is calculated. The long term memory duration is also evaluated, by combining the present results with previous ones worked out by this author. Water with its protons and oxygen constituents, plays a fundamental role in accomplishing these tasks.

1 – Introduction

Water is the most important substance of the world. Without it, life as is understood by many people, perhaps could not be established on the earth [1,2]. Meanwhile, hydrogen-bond kinetics [3] seems to play a fundamental role in the transport properties of water. In a recent paper [4], we have proposed that protons in liquid water behave as a Fermi gas. The memory's retention time of living beings [5] also has been associated to the number of protons contained in a certain volume of the memory device. The study developed in [5] was inspired in the works of Tononi [6] and Tegmark [7]. In reference [8] was put forward that the Darwin's time is proportional to the volume of the memory device, where the constant of proportionality depends only on fundamentals physics constants. The results obtained in [8] were put in a sound basis in reference [9]. We considered the Darwin's time [8,9], the very-long-term memory of living beings, as being registered in the "oldest rocks that provide clues to life distant past", as was pointed out by Joyce [10] (please see also A. Damineli and D. Damineli [11]).

While the very-long-term (VLT) memory is tied to the volume of the memory device (MD), as it happens with the Darwin's time (DT), we expect other kinds of memories show a dependence on the surface area of the MD. In this work we will explore this, by extending the holographic principle (HP) [12,13,14] to a universe in two dimensions as a means to accomplish this task. Besides this by combining the results of the present work with the previous one [9], we also get an estimation of the long term (LT) memory.

2- Holography in two dimensions

Let us extend the HP to a two dimensional (2-D) universe represented by a spherical surface. We adopt the prescriptions outlined by McMahon [14], but adapted to the two dimensional case. Here are the postulates of the HP in 2-D.

- The total information content in a spherical-surface universe is equivalent to a theory which lives on one of its maximum circle.

- The maximum circle perimeter contains at mos a single degree of freedom per unit cell length.

2A – Working memory and holography in 2-D

In this sub-section we will investigate the proposal that the retention time of the work memory (WM) depends on the surface area of the memory device. Let us take our two dimensional universe as a spherical shell of radius R. We consider the stationary condition for the free energy of the problem, in a process undergoing an isothermal transformation. We write

$$\Delta F = \Delta U - T\Delta S = 0. \qquad (1)$$

In (1), ΔF, ΔU and ΔS are variations of free and internal energies and of the entropy, respectively. In an analogous way we have done in reference [9], here we also make correlations between entropy and information, but is the information encoded in the maximum circle perimeter which is take in account. Remember: - we are considering the holographic principle in two dimensions! Now let us define the quantities present in relation (1)

$$\Delta U = hc/(2R), \tag{2}$$

$$\Delta S = \frac{1}{2}(P/P_0) = [(2Mc)/\hbar]\pi R, \tag{3}$$

$$T = h/(2\tau_W), \; (k_B = 1). \tag{4}$$

In (3), P is the perimeter of the maximum circle, and $P_0 = \hbar/(2Mc)$, is the size of the unit cell, being M the proton mass (two protons for each water molecule).

It is worth to stress that protons current plays a fundamental role in the transport properties of water. This liquid fills a great portion of the memory device (a portion of the brain). We observe that P_0 is half of the reduced Compton length of the proton, once each water molecule has two protons.

Using relations (2), (3) and (4) in (1) and solving for τ_W, we have

$$\tau_W = (2M/\hbar)\, \pi R^2. \tag{5}$$

Therefore we found that the time of retention of the working memory (τ_W) is proportional to the area of the memory device.

It is interesting to estimate τ_W for a spherical memory device having a volume of 1.8 cm^3. This gives an area limited by the great circle equal to 1.79 x 10^{-4} m^2. Putting numbers in relation (5), we get

$$\tau_W \cong 5.67 \times 10^3 \text{ s} \cong 94.5 \text{ min}. \tag{6}$$

We compare this result with a statement quoted by S. Mapa and H. E. Borges [15], that a type of memory which they call working memory may persist by one or more hours.

2B – Micro-memory device and holography in 2-D

In reference [9] we found that the oxygen nucleus of water may behave as a micro-memory device, exhibiting a very long retention time very close to the Darwin's time. There, applying the holographic principle (HP) to the oxygen nucleus, we got a characteristic time τ_O proportional to the volume of it.

In this sub-section we intend to apply the HP in the 2-D case, as a means to obtain a characteristic time which depends on the area limited by a maximum circle at the surface of the oxygen nucleus. We notice that according the here proposed HP in 2-D, the maximum circle perimeter contains at most a single degree of freedom per Planck length. Taking in account these premises and working in analogous way we have done in sub-section 2A, we get

$$\tau_O^{S} = (M_{Pl}/\hbar)\,(16)^{2/3}\,\pi\,R_p^{2}. \qquad (7)$$

In (7), M_{Pl} is the Planck mass and R_p is the proton radius. We also considered the liquid drop model of nucleus, so that the volume of the oxygen nucleus was taken as approximately sixteen times the proton volume. Putting numbers in (7), we obtain

$$\tau_O^{S} \cong 2.9 \times 10^{-3}\ \mathrm{s} = 2.9\ \mathrm{ms}. \qquad (8)$$

It seems that the time interval we get in (8) has some kind of experimental observation. As was pointed out by Wittmann [17]: "Simultaneity of two acoustic stimuli is detected with time intervals below to approximately 2 to 3 ms. Only above this temporal threshold, are they perceived as temporally separate.” Wittmann [17] quoted this result from experimental findings first published by Ira J. Hirsh [18].

3 – Short-term memory

Short-term (ST) memory is the capacity for holding a small amount of information in mind in an active, readily available state for a short period of time. We quoted this definition as presented by Wikipedia [19]. Yet according ref. [19], the duration of the ST memory (when rehearsal or active maintenance is prevented) is believed to be in the order of seconds.

The geometric average of the two times of duration estimated in this paper, namely τ_W, given by (5) and τ_O^S, given by (8), seems to be appropriated to account for this time scale. Therefore let us write

$$\tau_{ST} = (\tau_W \ \tau_O^S)^{1/2}. \tag{9}$$

Putting numbers in relation (9) we obtain

$$\tau_{ST} \cong 4.0 \text{ s.} \tag{10}$$

A ST memory duration time of 18 seconds has been quoted in ref. [19].

4 – Long-term memory

In ref. [9], we have used the holographic principle (HP) to estimate the Darwin's time τ_D and the Oxygen time τ_O. We found that the Oxygen time is proportional to the volume of the oxygen nucleus (micro-memory device) and the Darwin's time is proportional to the volume (macroscopic) of the memory device. Meanwhile in previous sections of this paper, by using the HP applied to a 2-D universe, we have estimated memories retention times which goes with the surface area of the oxygen nucleus, the temporal fusion threshold τ_O^S, and that which goes with the surface area of the macro-memory device, namely the working memory time τ_W.

In this section we propose the bold hypothesis that in order to estimate the long-term memory retention time, τ_{LT}, these four time durations must be considered at equal footing. With these ideas in mind, we define

$$\tau_{LT} = (\tau_D\ \tau_O\ \tau_W\ \tau_O^S)^{1/4}. \tag{11}$$

Numerical evaluation of (11) follows. First we consider $\tau_D = 4.3 \times 10^{16}$ s (ref. [8]), $\tau_O = 4.06 \times 10^{16}$ s (ref. [9]), $\tau_W = 5.67 \times 10^3$ s and $\tau_O^S = 2.9 \times 10^{-3}$ s, both evaluated in the present work. Inserting these numbers in equation (11) we get

$$\tau_{LT} \cong 4.11 \times 10^8 \text{ s} \cong 13 \text{ years}. \tag{12A}$$

Alternatively we may consider that

$$\tau_D = \tau_O = 12.3 \times 10^{16} \text{ s},$$

quoted from fig. 7 of reference [11], a paper by A. Damineli and D. Damineli. We notice that these last numbers for τ_D and τ_O, which corresponds to the previous ones multiplied by a factor of 3, can be found through a reanalysis of reasons which lead to relation (2) of ref. [8] and relation (12) of ref. [9]. Taking these new values for τ_D and τ_O and maintaining those of τ_W and $\tau_O{}^S$, we obtain from (11) the new value for the time duration of the LT memory

$$\tau_{LT}|_{new} \cong 7.06 \text{ x } 10^8 \text{ s} \cong 22.4 \text{ years.} \qquad (12B)$$

As was pointed out by Kendra Cherry [20], "While long-term memory is also susceptible to the forgetting process, long-term memories can last for a matter of days to as long as many decades."

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