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Regular article

Operations of Quantum Measuring Systems and the Holographic Principle

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Abstract. Based on the author's previous argument of the constant existence of the subject of quantum measurement in the framework of the classicalized holographic tensor network, for two quantum measuring systems M_1 and M_2 in the bulk spacetime, we calculate the result of the processes $(((M_1)_{\rm I} - M_1)_{\rm II} + M_2)_{\rm III}$ as the subject of quantum measurement. This process is obtained from the process $(((M_1)_{\rm I} + M_2)_{\rm II} - M_1)_{\rm III}$ by swapping processes II and III. The latter process is within the Lorentzian regime of spacetime and results in the quantum measuring system M_2. Therefore, we conclude that the objective result is also M_2.

Keywords: Quantum Measurement; Holographic Principle; Wick Rotation; Classicalization.

1 Introduction

This article is the fourth in a series [1–3] to investigate the links between quantum measuring systems and the holographic principle [4–8], and is positioned as a supplementary article to Ref. [2]. In Ref. [2], in the framework of the classicalized holographic tensor network in three spacetime dimensions [9–14], we showed the constant existence of the subject of quantum measurement by the temporal analytic continuation of the complex-valued quantum probability amplitudes of non-relativistic free particles in real time (the Lorentzian regime of spacetime) to their real-valued conditional probability densities in imaginary time (the Euclidean regime of spacetime) [1,2].[1]

In the Euclidean regime, we classicalize the quantum state of the hologram, that is, a strongly coupled conformal field theory (CFT) on the two-dimensional boundary spacetime [12–14]. The classicalized hologram $\mathcal{H}_E$ is the ground state $|\psi\rangle_{\mathrm{CFT}}$ of the boundary CFT with the Abelian restricted set $\mathcal{A}$ of the qubits observables in the presence of the superselection rule operator σ_3 (the one-qubit third Pauli matrix) [14,19]:

$$\mathcal{H}_E = (|\psi\rangle_{\mathrm{CFT}}, \mathcal{A}) \ . \tag{1}$$

In the Lorentzian regime, a quantum measuring system M in the bulk spacetime reads a quantum mechanical event (i.e., an eigenstate of the discrete measured observable) from a statistical mixture of events, which is obtained from the complete quantum decoherence as a result of the interaction between the quantum measured system and the macroscopic measurement apparatus [20,21]. The quantum measuring system M is the pair of a quantum mechanical event-reading system ψ with its discrete meter variable $\widehat{\mathfrak{M}}$ [22] and a quantum-field-theoretical macroscopic Bose–Einstein condensate A [23]

$$M = (\psi, A) \tag{2}$$

in the presence of the von Neumann-type interaction [24,25] between them [22].

In this article, we consider operations of quantum measuring systems. As important operations, we start from a single quantum measuring system M_1, and then we consider the fusion of M_1 and another quantum measuring system M_2 as a single quantum measuring system in total. The resultant quantum measuring system has the quantum mechanical system $\psi_{1,2}$, which is a quantum mechanically entangled system of ψ_1 and ψ_2 in the diagonal eigenbasis of the discrete composite meter variable $\widehat{\mathfrak{M}}_1 \otimes \widehat{\mathfrak{M}}_2$, and a composite system of A_1 and A_2 in the presence of the von Neumann-type interaction between them:

$$((M_1)_{\mathrm{I}} + M_2)_{\mathrm{II}} = (\psi_{1,2}, A_1 \otimes A_2) \ . \tag{3}$$

Here, we note that $\psi_{1,2}$ is not the tensor product $\psi_1 \otimes \psi_2$.

Our objective is to calculate the subject of quantum measurement given by the following process:

$$(((M_1)_{\mathrm{I}} - M_1)_{\mathrm{II}} + M_2)_{\mathrm{III}} \ . \tag{4}$$

This problem was not addressed in Ref. [2].

Within the Lorentzian regime, we cannot calculate this equation because, after process II, the quantum measuring system $(M_1)_{\mathrm{I}}$ is the empty system $M_\emptyset$. However, owing to the constant existence of the subject of quantum measurement, we can calculate this equation.

[1] We translate the term *subject* into the event reading by a quantum measurement [2]. In this article, the term *quantum measurement* refers to a projective quantum measurement in the ensemble interpretation of quantum mechanics [15–18].

The rest of this article is organized as follows. In the next section, we perform the calculation of Eq. (4) and obtain the result M_2 as the subject of quantum measurement (not just as a quantum system). In the final section, we conclude the article with some remarks.

2 Calculation

The theoretical advance obtained in Ref. [2] is the constant existence of the subject of quantum measurement. Specifically, we argued that the empty quantum measuring system $M_\emptyset$ in the Lorentzian regime is equivalent to the classicalized hologram in the Euclidean regime as the subject of quantum measurement:

$$M_\emptyset \simeq \mathcal{H}_E \, . \tag{5}$$

Because of the constant existence of the subject of quantum measurement, we can equate the following two processes:

$$\begin{aligned}(((M_1)_{\mathrm{I}} - M_1)_{\mathrm{II}} + M_2)_{\mathrm{III}} &= (M_2 + ((M_1)_{\mathrm{I}} - M_1)_{\mathrm{II}})_{\mathrm{III}} \\ &= (((M_1)_{\mathrm{I}} + M_2)_{\mathrm{II}} - M_1)_{\mathrm{III}} \, ,\end{aligned} \tag{6}$$

where we swap processes II and III. For this equation, see Figs. 1 and 2.

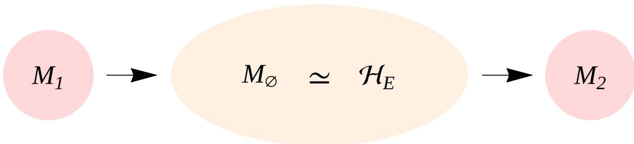

Figure 1: Schematic of processes I (left), II (middle), and III (right) on the left-hand side of Eq. (6).

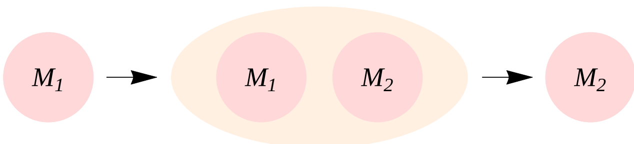

Figure 2: Schematic of processes I (left), II (middle), and III (right) on the right-hand side of Eq. (6).

Here, we can calculate the right-hand side of Eq. (6) because it is within the Lorentzian regime. This equation means the following three temporally successive processes:

I Preparation of the single quantum measuring system M_1.

II Preparation of another quantum measuring system M_2 and the quantum mechanical entanglement of it with M_1 as in Eq. (3).

III Contraction of system M_1 in the composite system $((M_1)_{\rm I} + M_2)_{\rm II}$. Then, we obtain system M_2.

Obviously, these three processes keep the subject of quantum measurement being unity and we obtain the result

$$(((M_1)_{\rm I} + M_2)_{\rm II} - M_1)_{\rm III} = M_2 \tag{7}$$

as the subject of quantum measurement.

Using the swap relation (6), we obtain the result of the objective calculation from Eq. (7):

$$(((M_1)_{\rm I} - M_1)_{\rm II} + M_2)_{\rm III} = M_2 \; . \tag{8}$$

3 Conclusion

In this article, based on the constant existence of the subject of quantum measurement, we suggest the problem of calculating Eq. (4). This calculation was not done in Ref. [2] and we have done it here by using the swap relation (6) of processes II and III in this equation. In the following, we remark on both sides in this swap relation (6).

On the right-hand side of Eq. (6), that is, Eq. (7), all of the three processes I, II, and III are done within the Lorentzian regime (L):

$$(7) : \text{I (L)} \to \text{II (L)} \to \text{III (L)} \; . \tag{9}$$

In principle, this process can be realized artificially.

On the other hand, on the left-hand side of Eq. (6), that is, Eq. (8), processes I and III are done in the Lorentzian regime, and process II is completed in the Euclidean regime (E):

$$(8) : \text{I (L)} \to \text{II (E)} \to \text{III (L)} \; . \tag{10}$$

This process is not an artifact.

The constant existence of the subject of quantum measurement implies that the results of these two processes (7) and (8) are the same system M_2 and thus are equivalent to each other as the subject of quantum measurement (not just as a quantum system).

Data Availability

The manuscript has no associated data or the data will not be deposited.

Conflicts of Interest

The author declares that there is no conflict of interest.

Ethical Considerations

The author has diligently addressed ethical concerns, such as informed consent, plagiarism data fabrication, misconduct, falsification, double publication, redundancy, submission, and other related matters.

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