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Theoretical Possibilities of Head Transplant

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Abstract

Zielinski & Sokal [1] proposed theoretical justifications against the spinal cord regeneration after total transection. Information loss is the main concern in their claim. Thus, their claim theoretically concluded that head transplant is not possible due to information loss. In this paper, we use methodology of "Shannon entropy" for ideal, random, and functional equivalence mechanisms to show that functional equivalence mechanism is the best way for minimum loss of information during head transplant. Moreover, to stop the loss of minimum information during head transplant, design of a spinal cord logic circuit bridge (SCLCB) is provided. It is a reversible logic circuit, consisting of NOT, AND and OR gates. We get the inequality $H_{ideal} \leq H_{functional} < H_{random}$ and it concludes that spinal cord regeneration is theoretically possible if neurosurgeons identify each class F_i with functional equivalence mechanisms at most matching. SCLCB has the potential to take two binary inputs at time t_1 and it can give the same outputs at time t_2. Using logic gate operations and binary digits, we show that SCLCB transmits nerve signals during spinal cord injury. SCLCB is a logic circuit analogy of spinal cord quantum bridge (SCQB). Later, using the idea of free energy of a thermodynamical system, we show that there is no information loss if surgeons use SCLCB during head transplant to stop loss of information due to spinal cord transection. Thus, we disprove the claim of Zielinski and Sokal and conclude that head transplant is theoretically possible but technological developments should be needed.

Keywords: Spinal cord regeneration; Entropy; Laws of thermodynamics; Head transplant; Logic gates; SCLGB.

Background

In 2013, Canavero [2] announced that full head (or body) transplant of a human is possible. Since then, Canavero & Ren [3] have been facing criticisms. Often, ideas of Canavero [2] or related procedural developments by Canavero & Ren [4] are considered to be medically impossible tasks and unethical. One may find many articles on medical impossibilities as well as ethical issues related to human head transplantation [5-7], but only a few groups of researchers are supporting possibilities of human head transplantation [8,9]. In short, Canavero's HEAVEN (The head anastomosis venture project) with spinal linkage (project GEMINI) [2] is a matter of discussion from various sides, in spite of Ren & Canavero's hope [9].

Amidst all the debates regarding possibilities and impossibilities related to head transplantation in humans, an article [1] attracted our attention. In 2016, Zielinski & Sokal [1] considered a hypothesis and proved that full spinal cord regeneration after total transection is not possible. Their hypothesis concludes that a head transplant with a cent percent success rate is not possible. Their hypothesis is cited below.

"The hypothesis is that full spinal cord restoration after its transection is not possible due to irreversible loss of information about its structure, needed to restore the connections."

Moreover, Zielinski & Sokal [1] considered following three assumptions to verify the above hypothesis.

i. There are two million of axons in the pyramidal tract in the cervical region and these axons are important for spinal cord regeneration and restoration of adequate quality of life of a patient.

ii. The second assumption is that the regeneration of damaged spinal cord should lead to axonal growth through the lesion site from the proximal end of the cord to the distal end and their re-connections with adequate target cells with loss of distal parts of axons, below the level of transection and there is an equal number of targets.

iii. The axonal growth of the severed spinal cord is made fully possible.

Zielinski & Sokal [1] used some basic mathematical justifications (using permutations) behind their claims, which cannot be neglected at first glance. They also claimed that there is a lack of mathematical background in this area of research and thus, unnecessary expenditures of high research funds. In this paper, we provide mathematical justifications and prove that head transplant with cent percent success rate is possible in a theoretical sense.

Hypothesis

We consider the following hypothesis:

"Head transplant is possible without any loss of information. Moreover, a logic circuit bridge (SCLCB) can be used to transmit nerve signals in case of transection of the spinal cord due to spinal cord injury."

Shannon Entropy, Uncertainty and Information Loss during Head Transplant

Zielinski & Sokal [1] considered that there are two million pyramidal axons in the spinal cord. They considered the spinal cord as an open system whose entropy would be lost after injury. After transection due to injury, the proximal part and the distal part would be formed, and each of them would have new entropy. While reconnecting the proximal part with the distal part, if one makes incorrect reconnections, then the brain may have some problems to reorganise, refining its own connectivity due to the brain plasticity [10]. Here, we show mathematically that head transplant is possible, and we provide some ways to stop loss of information due to entropy change. Let us rename two million pyramidal axons as A_1, A_2, ..., $A_{2,000,000}$, respectively. If p_i be the probability of establishing correct interconnection of a pyramidal axon A_i from proximal part to its counter distal part, then P_i=1/2,000,000, for all i=1,2,3, … ,2000000. In this case, if H_{radom} be the Shannon [11] entropy, then $H_{random} = -\Sigma_{i=1}^{2,000,000} p_i \log_2 p_i = \log_2 2{,}000{,}000$. Thus, maximum uncertainty is obtained when one wants to establish interconnections randomly. We consider an ideal (hypothetical) case where interconnection after total transection will be done as it was before total transaction.

In this case, if p_i' be the probability of establishing correct interconnection of a a pyramidal axon A_i from the proximal part to its counter distal part, then p_i'=1, for all i=1,2,...,2,000,000. Let H_{ideal} be the Shannon entropy [11] for the ideal case, then $H_{ideal} = -\sum_{i=1}^{2,000,000} p_i' \log_2 p_i'$ = 0. Thus, the Shannon entropy of the ideal case is zero i.e., there is no uncertainty in the ideal (hypothetical) case. It is the only case of spinal cord regeneration when the Shannon entropy is zero. Zielinski & Sokal [1] assumed random reconnections and thus, they obtained 2,000,000! permutations. But, why will neurosurgeons establish random interconnections of pyramidal axons? Ren et al. [12] discussed various medical methods along with experimental evidences regarding possibilities of spinal cord fusion, axons regeneration, etc. Moreover, they quoted the following paragraph from Bucy et al. [13].

"The pyramidal tract is not essential to useful control of the skeletal musculature. In the absence of the corticospinal fibers, other fiber systems, particularly some multineuronal mechanism passing through the mesencephalic tegmentum, can produce useful, well-coordinated, strong, and delicate movements of the extremities."

Thus, the above paragraph encourages us to develop mathematical possibilities with functionally equivalent mechanisms. Let us subdivide 2,000,000 pyramidal axons into some classes based on their functional equivalence and non-functional equivalence mechanisms. Let F_1, F_2, ..., F_K be K classes having functional equivalence mechanisms and F_{K+1} is a class of pyramidal axons based on non-functional equivalence mechanism. We assume $|F_1|+|F_2|+...+|F_K| = 2{,}000{,}000 - n$ and $|F_{K+1}| = n$, where n<<2,000,000. Due to functional equivalence mechanisms, the Shannon entropy for class F_i (symbolically H_{F_i}) is zero, for i=1,2,3, … ,k $H_{F_{K+1}} = \log_2 n$ due to non-functional equivalence mechanism. Let $H_{functional}$ be the Shannon entropy collectively based on functional equivalence and non-functional equivalence mechanisms. Then due to Shannon [11], we obtain $H_{functional} = \sum_{i=1}^{K+1} H_{F_i} = \log_2 n$. Since n<<2,000,000, thus $H_{ideal} \leq H_{functional} < H_{random}$. Hence, it can be concluded that functions will be restored approximate to maximum due to reconnections as long as the mismatch is not extreme [11]. Since, the Shannon entropy of information theory is connected to the second law of thermodynamics [14], thus we urged against the claim of Zielinski & Sokal [1]. Hence, we conclude that spinal cord regeneration is theoretically possible if neurosurgeons identify identify each class F_i with functional equivalence mechanisms at most matching.

Spinal Cord Logic Circuit Bridge (SCLCB)

Recently, Nie et al. [15] showed that transmissions of nerve signals after spinal cord injury are possible in the quantum realm and thus, they proposed spinal cord quantum bridge (SCQB). It inspires us to build a logic circuit using only three logical operators

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AND, OR, and NOT. We call this logic circuit as Spinal Cord Logic Circuit Bridge (SCLCB). In figure1, SCLCB has inputs X and Y on its right side and left side respectively. Again, it has outputs X and Y on its left side and right side respectively. This arrangement helps SCLCB to act as a bridge for transmissions of nerve signals between two parts of a transected spinal cord during spinal cord injury.

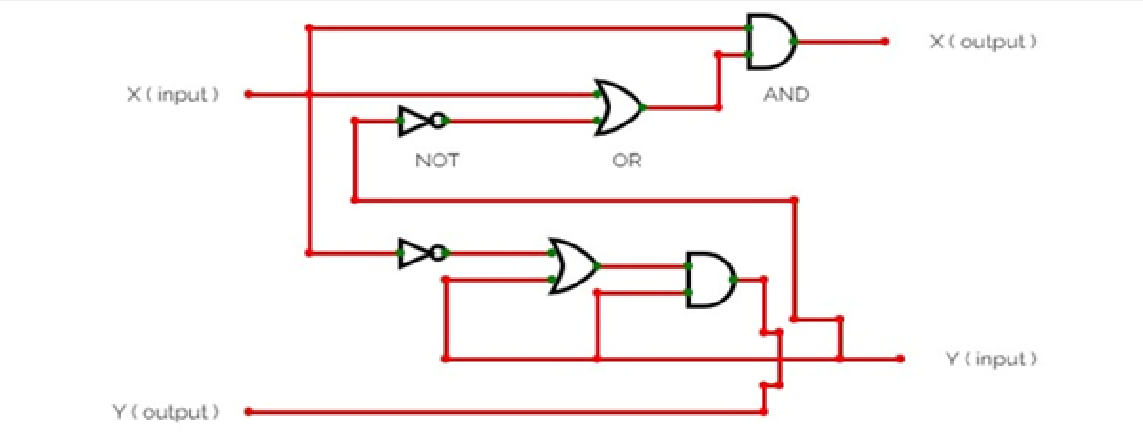

Figure 1: Spinal Cord Logic Circuit Bridge (SCLCB).

In Figure 2a, a transected spinal cord is shown. Here, X represents transmissions of nerve signals in upward direction and Y represents transmissions of nerve signals in downward direction. More elaborately, X represents transmissions of sensory nerve signals from peripheral nerves to central nerves and Y represents transmissions of motor nerve signals from central nerves to outer peripheral nerves. But due to transection, transmissions of nerve signals are stopped, and it is shown in Figure 2a.

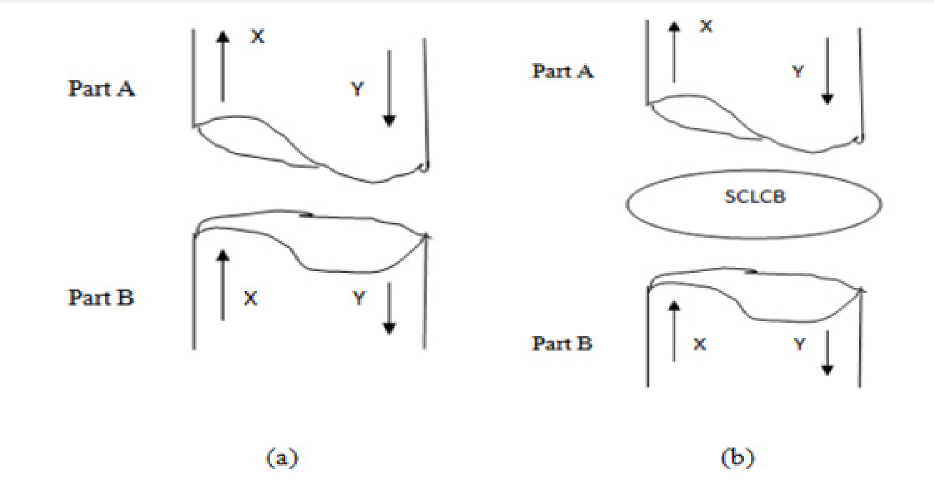

Figure 2: (a) Spinal cord injured (SCI) and transected (b) SCLCB between transected spinal cord.

In Figure 2b, we implant SCLCB between two breakpoints Part A and Part B of the transected spinal cord. While implanting SCLCB, we are to connect X(input) and Y(output) with breakpoint Part B and X(output) and Y(input) with breakpoint Part A of the transected spinal cord. SCLCB takes both X and Y simultaneously as inputs at time t_1 and transmits signals X and Y as outputs at time t_2. For example, if we consider X=1 and Y=1 as inputs at time t_1 i.e., transmissions of nerve signals in both directions through SCLCB at time t_1, then we can easily check that SCLCB gives outputs X=1 and Y=1 at time t_2. One may check for other three cases of inputs viz. (i) X=1 and Y=0 (ii) X= 0 and Y= 1, and (iii) X= 0

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and Y=0. Thus, we propose that SCLCB can be implanted between two parts of the spinal cord after transection due to spinal cord injury. Thus, we propose that transmissions of nerve signals are possible through SCLCB. Since, both SCLCB and SCQB [15] show possibilities of transmissions of nerve signals during spinal cord injury, thus we theoretically predict that head transplant is possible in both non-quantum and quantum realms.

Information Loss in Digital Circuit and SCLCB

Recently, Häenninen et al. [16] established methodologies to quantify irreversible information loss in digital circuits. The property of mapping a set of input bits onto a set of outputs in a logical operation is called logical reversibility [16]. In a logically reversible computation, all inputs can be known from all outputs. Physical reversibility occurs in an isolated system. According to Häenninen et al. [16], a logically irreversible computation can be obtained in an isolated system. One may refer to Keyes & Landauer [17] for energy dissipation in logic gates. We cite the following paragraph from Häenninen et al. [16].

"One bit can be in two states, so the associated entropy is $S = k_\beta ln2$ an unknown bit, changing either 0 or 1 to a NULL state, means there is a transfer of this entropy to the environment with associated free energy:

$$\Delta E = TS = k_\beta Tln2$$

Thus, a physical implementation of a bit ensures or any logical operation that loses 1 bit of information must necessarily dissipate an amount of heat greater than or equal to ΔE..."

In case of logical reversible computation, if the computation can be made sufficiently slow, then dissipation of arbitrary small amounts of energy occurs [18]. This claim is quite similar to the claim made by Ren et al. [12] in favour of extremely sharp cuts. Moreover, Bennett [18] suggested that minimization of the energy dissipation can be obtained near thermodynamic equilibrium. Thus, functional equivalence mechanism and $H_{functional}$ may be important ideas to neurosurgeons for human head transplantation. Bennett [18] showed that a logically irreversible computation can be made logically reversible in each step. It is important to note that SCLCB is a reversible logic circuit [16] because one can determine both inputs from outputs. Thus, there is no information loss if neurosurgeons use SCLCB during head transplant. Hence, we can conclude that there is no dissipation of energy in SCLCB [17,18]. More suitable chemical and electronic technologies, viz. molecular logic gates [19], electronic circuit design [20], etc. may be used to make SCLCB more effective. Recently, clinical trials on partial restoration of spinal cord neural continuity were done [21-23]. Thus, we should remain optimistic about head transplant. Hence, we now justify our hypothesis.

Conclusion

Zielinski & Sokal [1] claimed that full spinal cord regeneration after total transection is not possible due to entropy change, and thus they indirectly concluded that head transplant is not possible. To prove their claim, they considered one hypothesis based on three assumptions. By considering the same assumptions, we proved that head transplant is possible since there is no case of information loss if neurosurgeons use functional equivalence mechanism and SCLCB. We showed that functional equivalence mechanism results in minimum loss of information. Moreover, we designed Spinal Cord Logic Circuit Bridge (SCLCB). It is a reversible logic circuit. Hence, it can be used to stop information loss during human head transplantation. Both SCLCB and SCQB [15] show theoretical possibilities of head transplantation in both non-quantum and quantum realms. Since, procedures of head transplantation require sophistications in medical and engineering technologies, thus we assume that the domain of head transplantation research will attract attention of several interdisciplinary fields. Moreover, we hope that our theoretical ideas of this paper will find their suitable uses in head transplant research in future.

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