***Quantifying casual emergence shows that macro can beat micro***

1. ***ABSTRACT***

In a complex system, emergence can happen at any level from micro to macro. Causation and effectiveness at different levels are need to be calculated to describe the efficiency of the system which can be explained based on the prediction probability of the effects/future elements.

1. ***INTRODUCTION***

It is widely assumed that, once a micro level is fixed, macro levels are fixed too, a relation called supervenience. It is also assumed that, although macro descriptions may be convenient, only the micro level is causally complete, because it includes every detail, thus leaving no room for causation at the macro level. However, this assumption can only be evaluated under a proper measure of causation. Here, we use a measure effective information (EI) that depends on both the effectiveness of a system’s mechanisms and the size of its state space: EI is higher the more the mechanisms constrain the system’s possible past and future states.

1. ***Theory***

Cause information (CI) *=*

Effect information (EI)*=*

*Effectiveness (Eff) = Effective Information (EI)/ size of the system(logn\_2)*

*Micro states are formed with the combination of 2 micro elements where micro elements are formed with binary numbers (0,1). Macro states are the output of the AND gate on 2 micro states. For 4-bit micro states, there are 16 possible micro states and 16 macro states. Macro elements are mapping of micro elements to the possible system states at macro level.*

*Effectiveness at micro level and macro level shows whether emergence/reduction is happening. Effectiveness depends on EI and system size i.e.; Effectiveness is directly proportional to the EI and inversely proportional to the size of the system. If EI>0, then emergence occurs, else if EI<0, then reduction occurs.*

***4.Experiment***

*Consider no of bits in micro state as n. Initialize the probability transition matrix for the mechanisms in micro state and macro state. Find the possible micro states and macro states and find the EI for both states. Based on EI, emergence/reduction can be identified.*

*micro elements are {00,01,10,11}, micro states = {0000, 0001, ……., 1111}, macro states are {0000, 0001, …., 1111}, macro elements = {OFF, ON}, mapping of macro elements with micro elements are OFF = {00,01,10} and ON = {11}.*

***5.Algorithm***

Initialize EI = 0

Let n = no of bits in a state

Sm = all possible states

for each pair (Si, Sj) in Sm

EI += KL(P(Si/Sj), U) or Euclidean(P(Si, Sj), U) where U= 1/(n\*n)

Calculate EI for both micro and macro states.

***6. RESULTS***

With KL Divergence n = 4, EI(micro) = 1.16 and EI(macro) = 1.56, Eff(micro) = 29.03% and Eff(macro) = 78.11%.

With Kmeans using Euclidean distance as key to find the dissimilarity, n = 4, EI(micro) = 1.10 and EI(macro) = 1.31, Eff(micro) = 27.61% and Eff(macro) = 65.64%

Eff(macro) > Eff(micro) with both KL Divergence and Kmeans because Eff not only depends on the EI but also inversely related to the state space.so as state space of micro states are greater than the macro states, effectiveness of predicting the macro elements is better than the micro states i.e., mechanisms at macro level are very predictive than the mechanisms at micro level.

***Conclusion***

Finally, we conclude Causal interactions are happen-ing at macro level because complex, multilevel systems such as brains work at a macro level because, in biological systems, selection processes must deal with unpredictability and lead to degeneracy.

***References***

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