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Figure 12 in Klaus Krippendorff's 'Ross Ashby's information theory: a bit of history, some solutions to problems, and what we face today', International Journal of General Systems, 38, 189-212, 2009

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CORRECTION

Figure 12 in Klaus Krippendorff's 'Ross Ashby's information theory: a bit of history, some solutions to problems, and what we face today', *International Journal of General Systems*, 38, 189–212, 2009

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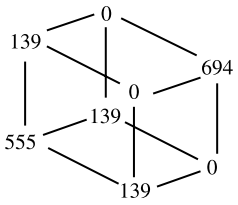
I regret that two of the quantities in Figure 12 of Krippendorff (2009) were incorrect. Ironically labelled 'The Correct Account of Interactions…' these quantities should instead be as follows:



$I(ABC{\rightarrow}AB{:}AC{:}BC) = 0.25$ bits $\neq Q(ABC) = 0.00$
$I(AB{:}AC{:}BC{\rightarrow}AB{:}AC) = 0.10$ bits $\neq T(B{:}C) = 0.35$
$I(AB{:}AC{\rightarrow}AB{:}C) = 0.35$ bits $= T(A{:}C)$
$I(AB{:}C{\rightarrow}A{:}B{:}C) = 0.35$ bits $= T(A{:}B)$
$I(ABC{\rightarrow}A{:}B{:}C) = 1.05$ bits $= T(A{:}B{:}C)$

Figure 12. Correct accounts of the interaction information in data in Figure 6.

This error made the intended comparison less clear. While Q-quantities turned out not to measure information in multi-variate interactions as assumed by information theorists, referred to in Krippendorff (1980, 2009), the resolution of this negative finding came with the discovery that $Q(ABC)$ was the difference between the correct amount of interaction information $I(ABC \rightarrow AB{:}AC{:}BC)$ and a measure of overdetermination or redundancy $R(AB{:}AC{:}BC)$ (Krippendorff 1980, p. 66):

$$Q(ABC) = I(ABC \rightarrow AB{:}AC{:}BC) - R(AB{:}AC{:}BC).$$

It shows Q not to be a stand-alone measure of either entropy or information but of the extent to which I exceeds R, explaining Q's odd behaviour, and resolving the common inability to interpret Q's negative values. This relationship gives rise to a measure of redundancy:

$$R(m_1) = I(m_0 \rightarrow m_1) - Q(m_0).$$

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For data in Figures 6 and 12:

$$R(AB{:}AC{:}BC) = I(ABC \rightarrow AB{:}AC{:}BC) - Q(ABC) = 0.25 - 0 = 0.25 \text{ bits}.$$

One may recognise this amount of redundancy in the difference between $T(B{:}C) = 0.35$ bits and the information lost when BC is removed from the data, $I(AB{:}AC{:}BC \rightarrow AB{:}AC) = 0.10$ bits. T quantifies the interaction in BC without reference to its context, I quantifies the same interaction but in the context of the interactions in AB and AC that together form a loop and imply part of BC.

The three-dimensional frequency distribution in Figure 7 can be reconstructed from any two faces of the data cube, a ternary interaction being absent and one binary interaction being redundant and ignorable without loss. This is reflected in the amount of redundancy, $R(AB{:}AC{:}BC) = 0 - (-1) = 1$ bit, which equals the amount of information in any one redundant binary interaction, $T(A{:}B)$, $T(A{:}C)$, or $T(B{:}C) = 1$ bit each.

For data in Figure 5, redundancy measures $R(AB{:}AC{:}BC) = 1 - 1 = 0$ bits. Indeed, the ternary interaction in this data cube is unique. The three faces of the data cube, AB, AC, and BC tell the analyst nothing about the frequency distribution in ABC. It is noteworthy that the absence of redundancy is the only condition under which $Q(m_0)$ correctly measures the information of an interaction, $I(m_0 \rightarrow m_1)$.

Whenever circularities exist in multi-variate data, Q-measures are confounded by the redundancy of their algebraic calculations. $R(m_1)$ can be negative, a condition that pertains when algebraic accounts of the interactions in a system under-determine these interactions. I am grateful to Leydesdorff (2009.4.17) for providing an example of this condition.

Leydesdorff discovered that the URL from which my old FORTRAN code for computing $I(m_i \rightarrow m_j)$ for up to 10 variables and 10 states each can be downloaded was changed to http://www.pdx.edu/sysc/research-discrete-multivariate-modeling [Accessed 6 April 2009].

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