

Shannon and measurable information

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Core question

How did information become a measurable quantity that could be analysed independently of the meaning of a message and used to design reliable communication systems?

Historical and evolutionary context

Telegraphy, telephony and radio had already created engineering problems of bandwidth, noise and coding. In 1928 Ralph Hartley proposed a logarithmic measure related to the number of possible symbol sequences. Claude Shannon's 1948 papers unified these concerns into a general mathematical theory of communication. The decisive move was to treat a source as a probability distribution over possible messages and to define information in terms of uncertainty rather than semantic content.

What could communities know before this transition?

Engineers could measure signal amplitude, frequency response and error rates, and could design codes pragmatically. PIO-072 had shown how communication detached messages from physical travel. The limitation was the absence of a general quantitative language for asking how much information a source produces, how much a channel can carry and how redundancy can be traded for reliability.

What changed?

Entropy quantified uncertainty at the source

Shannon defined a measure of source uncertainty with a logarithmic form related to probabilities. The same mathematical structure could describe binary symbols, alphabets or other discrete message ensembles. Information could therefore be compared across different physical implementations.

Channel capacity became a theoretical limit

The noisy-channel framework separated source, encoder, channel, decoder and destination. Shannon showed that reliable communication is possible below a channel capacity under suitable coding, while rates above capacity cannot be made arbitrarily reliable. Engineering acquired a limit theorem rather than only better hardware.

Redundancy became a resource rather than pure waste

Everyday language and engineered codes contain predictable structure. Shannon's framework showed how redundancy can support error detection and correction, while source coding can remove unnecessary repetition when efficiency is the goal.

Why could this capability emerge?

The theory depended on probability, telecommunication engineering, Boolean and switching ideas, wartime cryptography and the practical need to transmit signals through noisy channels. Bell Laboratories provided an environment where abstract mathematics and communication hardware were tightly coupled.

What later forms of knowledge did it enable?

Information theory enabled coding, data compression, digital storage and communication, and provided concepts later used in genetics, statistical physics, computing and machine learning. It also made possible engineering comparisons between systems that use very different physical media.

New limits and risks

Shannon information deliberately ignores semantic truth and value. A highly informative message in the technical sense can be false, harmful or meaningless to a receiver. Applying entropy metaphors outside well-defined probability models can therefore create false precision. Digital communication also creates new dependencies on coding standards and infrastructure, while increasing capacities for surveillance and traffic analysis.

What changed in the architecture of knowledge?

Information became a **quantifiable relation among possibilities, probabilities and channels**. Communication could be analysed at a level abstracted from both the message's meaning and the material carrying it.

Loss, exclusion and uncertainty

The history is often compressed into Shannon alone. Hartley, Nyquist, telegraph engineers, cryptanalysts and coding practitioners supplied essential antecedents. Shannon's theory also did not solve semantics, cognition or truth; later uses should not retrospectively attribute those broader claims to the 1948 framework.

Dependency map

- INDIRECT ← PIO-072 Telegraph and radio: knowledge travelling faster than people
- PARALLEL ← PIO-082 Turing and programmable computation
- DIRECT → PIO-090 Networks, simulation and machine learning

References

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