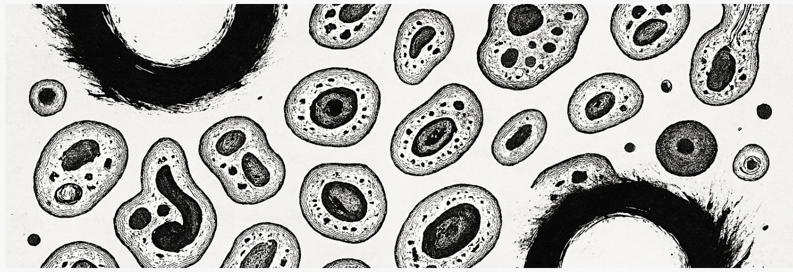
New Universal Mathematical Methods for Decoding First-Contact Messages—from Cells, Trees, and Even Aliens

Framework for intelligent information exchange inspired by fractals, complexity, information theory enables communication protocols between intelligent systems



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LONDON, UNITED KINGDOM, April 22, 2025 /EINPresswire.com/ -- Researchers led by Dr. Hector Zenil FRSM from the School of Biomedical Engineering and Imaging Sciences and the King's Institute for AI, King's College London, the Alan Turing Institute and Oxford Immune Algorithmics, have developed groundbreaking mathematical and computational frameworks that advance our capacity to encode, decode, and detect signals across unknown or extreme spatio-temporal scales and conditions. Three new studies, one published in the peer-reviewed journal Information Sciences (Elsevier) and two posted on the preprint ArXiv server, demonstrate powerful new tools for zero-knowledge communication, this is communication when both the sender and the receiver have very little knowledge about each other, such as lifetime scales. For example, trees life spans cover centuries while flies only days, how could these species ever communicate?

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> *Olaf Witkowski, Director of Cross Labs, and University of Tokyo*

The researchers introduced an innovative, zero-knowledge decoding method grounded in the principles of Algorithmic Information Theory that governs digital information, and fractals, a type of self-similar objects like the way in which cauliflowers are composed by smaller cauliflower-looking pieces. This type of universal decoding technique developed by the researchers requires no prior assumptions about the sender’s language peculiarities, effectively enabling receivers to reconstruct original messages sent through one-way communication channels as they were originally intended—critical for interpreting extraterrestrial signals but also animals or unfamiliar biological signals such as those shared between cells or neurons.

“Dr. Zenil's work resonates deeply with the broader Artificial Life effort to understand intelligences across radically different embodiments, scales, and substrates—life as it could be. By grounding message reconstruction in the intrinsic algorithmic structure of information itself, this principled approach stands out as one of the most promising frameworks I have encountered for first contact scenarios where no prior common ground exists.” Dr. Olaf Witkowski, Founding Director, Cross Labs, and Lecturer, University of Tokyo.

In this work, the Arecibo message, sent into space from the Arecibo radio telescope in Puerto Rico in the 1970s, was used as an example to illustrate the method. Using these mathematical and computational principles, the researchers successfully reconstructed the image in two dimensions from its unidimensional radio signal form in which it was originally transmitted to space. One of the papers also explored the concept of self-executing messages that require less assumptions on the receiver side where the message can also act as the carrier, and the carrier is also the message. This is like sending a computer together with a compressed computer file with a complete encyclopaedia rather than the Encyclopaedia file alone that the receiver may be able to read or execute or not.

“What I like about it is that it’s a mathematically rigorous approach to characterizing a transmission,” Brian McConnell, a computer scientist at Notion Labs in San Francisco, author of The Alien Communication Handbook: So We Received a Signal—Now What? Published By Springer Nature (Science News)

This body of work introduces a universal method based on what the researchers call Algorithmic Information Dynamics (AID) able to reconstruct the geometric dimensions and shape of a message or signal with no prior knowledge by applying an intervention analysis technique that consists in a trial-and-error approach to perturbing the object into multiple shapes guiding a search that favours highest content while minimizing for randomness. The researchers demonstrated the method's versatile capabilities by reconstructing various multidimensional spaces, including an MRI image of a knee embedded in a cube. Their perturbation analysis allowed them to identify the original dimensions by detecting complexity variations through downward spikes at specific dimensional partitions.

“With this set of foundational papers, we introduce the area of SETI semantics, which is not only relevant to hypothetical extraterrestrial intelligence but also crucial for understanding intelligent systems on Earth. Cells, fungi, plants, and animals communicate across scales and in forms very different from human communication yet exhibit intelligence that remains largely unknown to us. Our work provides tools to encode, decode, and comprehend such diverse communications.” said Dr. Hector Zenil FRSM, Lead researcher and Associate Professor at King’s College London.

Dr. Zenil adds, “paradoxically, it is the fact that we cannot compute something that introduces a type of key subjectivity that allows our algorithms to work by way of exploiting deficiencies to deduce the signal's intended geometric shape from its original 'envelop'. One this sorted, without this step, we would not have even a chance at understanding any message."

The papers have led to the establishment of a group called The Arrival Institute inspired by the movie with the same name, which for the first time offers tools to deal with coding and decoding meaning rather than the previous more hardware-driven discussions around SETI, such as the technical details of the sender or receiver such as carrier type or frequency. Thanks to these tools, we may have a small chance to ever be able to read it or understand it.

"The new approach frees prime numbers to serve a secondary purpose in parsing a message. Instead of being a guide to discover the format, they can now be used to confirm that the decoders found the correct solution," Douglas Vakoch, SETI researcher, president of METI International (Science News).

The papers bridge theoretical insights from information and communication theory, complexity science, fractal geometry, and topology, providing across-field robust tools applicable to areas ranging from astrobiology to bioinformatics to cryptography to artificial intelligence.

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