Using AI to Fine Tune the Search for Life

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Abstract

Astrobiologists seek to find life beyond Earth. The “Holy Grail” of Astrobiology research is to discover evidence of a second genesis of life – an origin of life that was independent from life’s origin on Earth. No formal consensus on the possibility for a second genesis of life exists, and opinions about the probability range from near zero to near unity. An extra-terrestrial example of life would help answer this question and settle the quandary of whether life is common in the Universe or exceedingly rare. Quantifying the “ordinariness” of life has far reaching philosophical implications that could even inform us about the future of intelligent, technology-wielding life on Earth (Bostrom 2007).

Life on Mars, one of our closest planetary neighbors, was considered a forgone conclusion as recently as the mid 20th century. What else besides an advanced civilization cultivating crops could have been responsible for the telescopically observed network of “canals” scarring its red surface? The “Advanced Martian Civilization” hypothesis had support from preeminent scientists, such as Giovanni Schiaparelli and Percival Lowell, but was relegated to the realm of pseudoscience when data from the Mariner spacecrafts in the 1970s failed to reveal any evidence for such civilizations. There is still no convincing evidence for life on Mars; however, several studies have at least raised one or two eyebrows (Mazur et al. 1978, McKay et al. 1996, Ruff and Farmer 2016).

The Mariner missions ushered in the era of modern space exploration at Mars, and with it an earnest search for life. In 1976, shortly after the Mariner missions, the Viking I & II landers delivered “positive” results from their Labeled Release (LR) experiments. Oxidants in the martian regolith are the generally accepted explanation for these results, but some argue that life is the most parsimonious explanation for the Viking data (Levin and Straat 2016). We still do not know if life existed, or exists, on Mars, but Mars was once habitable for the forms of life that took root on early Earth and certain places on Mars likely remain habitable (Davila et al. 2010, Ehlmann et al. 2016). Its potential habitability and proximity to Earth have kept Mars centered in the crosshairs of Astrobiological research for decades. However, icy ocean worlds – Titan, Europa and Enceladus – have garnered increasing attention from the Astrobiology community (National Academies of Sciences and Medicine 2022), partially because any evidence for

life on these worlds has a much higher chance of representing a second genesis whereas life on Mars could have potentially originated on Earth (or vice versa).

The problems we face in the search for life on Mars today mirror those that confronted Schiaparelli and Lowell: we do not have data of sufficient quality to answer the question definitively. One major difference is that Schiaparelli and Lowell had their prior probability for the expectation of life on Mars set at what must have been a fairly high value. By contrast, decades of null results for evidence of life on Mars have tuned our expectations such that all abiogenic explanations for any piece of would-be-evidence-for-life must be rigorously rejected before biotic explanations can be considered (e.g., Ruff and Farmer (2016), Oehler and Etiope (2017)). Perhaps one day, incontrovertible evidence for life on Mars will be found that will open the floodgates for a reinterpretation of evidence that, at present, is too dubious to consider. Until then, a high bar is rightly set for the standard of evidence (Neveu et al. 2018). If evidence of life exists on Mars, it is apparent that it will not be easy to find.

NASA developed a strategic exploration arc to hone in on the most likely places to find evidence of life on Mars. The strategy goes:

1. Follow the water;
2. Explore habitability;
3. Seek signs of life.

The “Follow the water” theme characterized missions from Mars Global Surveyor in 1996 to the Mars Atmospheric and Volatile EvolutioN orbiter in 2013. “Explore habitability” and “Seek signs of life” have overlapped, beginning in 2007 with the Phoenix lander and persisting to the present with the Perseverance rover at the Jezero Crater delta.

Despite technological and philosophical advances in Astrobiology and the overarching principles guiding NASA missions, a coherent and standard strategy for quantifying the probability of finding life in an arbitrarily chosen environment does not exist. For example, when we land in a deltaic system on Mars we do not know, and in fact do not have a strategy for knowing, which specific outcrop, or rocks within in an outcrop, will have the highest probability of containing signs of past life. What would such a “signs of life search strategy” look like?

In our recent paper (Warren-Rhodes et al. 2023), we propose that building a library of probability-of-life maps at nested spatial scales across many terrestrial-analog sites could be one way to address this question. Building probability maps relies on extensive microbial ecologic surveying, and can help us understand whether recognizable and predictable patterns characterize the distribution of terrestrial biosignatures. At our field site in Salar de Pajonales, Chile, we found that photosynthetic endolithic communities, the subject of our study, followed such a pattern. Their locations could be predicted using artificial intelligence (AI) models with an order of magnitude greater accuracy than a random search. Our study lays out a methodological framework for assessing a terrestrial analog site that combines geology, statistical ecology, and AI. The long-term vision is for the Astrobiology community to adopt and improve upon this strategy, and to build up a library of probability maps across many planetary-analog field sites. With a library of many biosignature probability maps across a diverse suite of analog sites, we can hope to extract trends and patterns in biosignature distributions that generalize across sites and that could inform the search for life in novel planetary environments.

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Astrobiology; Artificial Intelligence

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Conflicts of interest

The authors have declared that no competing interests exist.

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