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Are we alone?

Machine Learning for Detection of Life-Like Motility in Liquid Samples

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The Search for Life on Ocean Worlds

Jupiter's moon Europa and Saturn's moon Enceladus are expected to contain a liquid water ocean beneath their icy shells [1, 2]. All life we know relies on water, making these moons especially important targets for future missions to explore. To support such a mission, JPL is working on a suite of instruments capable of searching for life in liquid water samples called the Ocean Worlds Life Surveyor (OWLS). Finding life in these oceans could finally answer the question whether we are alone in the universe.

Life Moves

One possibility to search for life in water samples is by visually inspecting them for motility: the ability to move voluntarily. Motility is important to find nutrients and respond to potentially harmful stimuli and a distinct indicator of life. One of the instruments included in OWLS is a Digital Holographic Microscope (DHM) (Figure 2a). The DHM [3] can image a liquid water volume multiple times per second at submicron resolution with a depth of field that is 50 times larger than that of a conventional microscope. This makes it suitable for finding motile microorganisms.

Data Compression

The DHM generates 80 MB/s of data, which quickly exceeds the entire downlink capability (~75 MB) for a typical mission to Europa or Enceladus. Therefore, we must compress 100s of GBs of data and only return the most scientifically salient components to Earth. To solve this challenge, we developed an autonomous tool called Holographic Examination for Life-like Motility (HELM), which finds motile particles within DHM videos and extracts their spatiotemporal paths and small image crops. This effectively reduces the amount of data by orders of magnitude that needs to be transmitted to Earth while preserving most of its information content.

Automated Detection of Motility

HELM uses a multi-step algorithm to differentiate between motile and non-motile microorganisms.

1. Starting with the sequence of raw DHM images (Figure 2b) the median is subtracted. This increases the contrast for moving objects within the sequence and removes the static background.
2. Moving objects in the images (Figure 3a) are tracked (Figure 3b).
3. Track characteristics are extracted to prepare for Machine Learning (e.g., average speed, acceleration, turn radii, etc.).
4. Each track is classified as motile or non-motile using a random forest classifier

Data Prioritization and Downlink

Since the data generated by the DHM far exceeds downlink capabilities the individual samples are sorted by their priority. The priority of each sample is calculated based on its estimated science utility (e.g. number of motile particles) and how it differs from the other analyzed samples. The compressed data products of the most promising samples will then be downlinked to Earth (Figure 4), reducing the 100s of GB of raw data down to less than 100 MB.

Future Work

Going forward we will test the full system on samples from analog sites including Mono Lake, CA and Borup Fiord Pass, Canada. Through those tests, we will demonstrate the capabilities of OWLS and assess its readiness for future space missions.

Citations:

[1] Postberg, F.; Kempf, S.; Schmidt, J.; Brilliantov, N.; Beinsen, A.; Abel, B.; Buck, U.; Srama, R. Sodium salts in E-ring ice grainsfrom an ocean below the surface of Enceladus.Nature2009,459, 1098–1101.2.
[2] Carr, M.H.; Belton, M.J.; Chapman, C.R.; Davies, M.E.; Geissler, P.; Greenberg, R.; McEwen, A.S.; Tufts, B.R.; Greeley, R.; Sullivan,R. Evidence for a subsurface ocean on Europa.Nature1998,391, 363–365.
[3] J. Kent Wallace, Stephanie Rider, Eugene Serabyn, Jonas Kühn, Kurt Liewer, Jody Deming, Gordon Showalter, Chris Lindensmith, and Jay Nadeau, "Robust, compact implementation of an off-axis digital holographic microscope," Opt. Express 23, 17367-17378 (2015)

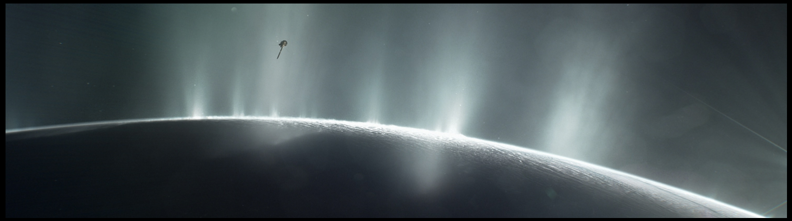

Figure 1: Artist's impression of a mission to Enceladus. A liquid water ocean is expected under its ice shell that might contain life. [image: NASA]

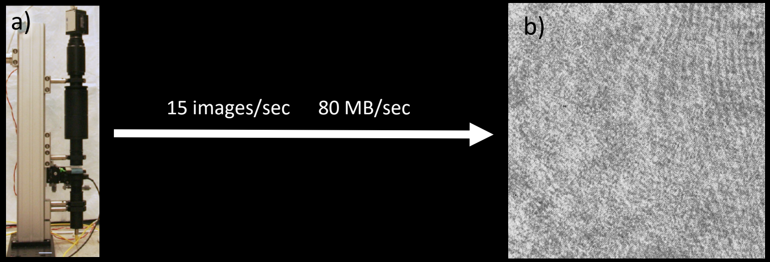

Figure 2: DHM (Digital Holographic Microscope) for visual inspection of liquid water samples: (a) DHM, (b) Raw hologram from the DHM that contains live bacteria.

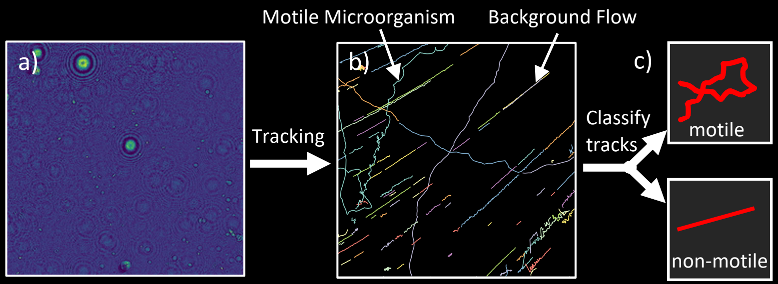

Figure 3: Tracking and classification of bacteria: (a) Hologram with background removed by median subtraction. (b) Tracks for moving objects generated by tracking algorithm. (c) Classification of tracks as motile or non-motile.

Figure 4: Sending the most life-like imagery back to Earth. HELM reduces the 100s of GB of raw DHM data down to ~75MB.