Use of a UAV for Water Sampling to Assist Remote Sensing of Bacterial Flora in Freshwater Environments

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Abstract
Ground truth data collection in bodies of water traditionally relies on the use of watercraft and manual sampling. The transport and cost associated with the use of this type of equipment, as well as the time required to reach the site of collection, may all be significantly reduced by the use of small unmanned aerial vehicles (UAV) or drones. In this project we evaluate the implementation of a modified UAV with the ability to collect a small volume of surface water up to 400m offshore. The bacterial flora found in the water of several locations in the Lake Ontario-Rochester Embayment area is then entered into a multi-year database that attempts to correlate hyperspectral data obtained by the Landsat 8 Operational Land Imager with the isolated bacterial species. We found that water collection using a consumer grade UAV facilitated sampling efforts, saving time and providing easy access to otherwise difficult to reach collection sites.

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Comments
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Our particular aim was to evaluate the use of UAV technology for water collection purposes. The overarching goal of the project is to build a comprehensive database that links the hyperspectral measurements of Landsat 8 OLI to the presence of specific microorganisms that form part of the bacterial flora in freshwater environments.

Abstract
Ground truth data collection in bodies of water traditionally relies on the use of watercraft and manual sampling. The transport and cost associated with the use of this type of equipment, as well as the time required to reach the site of collection, may all be significantly reduced by the use of small unmanned aerial vehicles (UAVs) or drones. In this project we evaluate the implementation of a modified UAV with the ability to collect a small volume of surface water up to 400m offshore. The bacterial flora found in the water of several locations in the Lake Ontario-Rochester Embayment area is then entered into a multi-year database that attempts to correlate hyperspectral data obtained by the Landsat 8 Operational Land Imager with the isolated bacterial species. We found that water collection using a consumer grade UAV facilitated sampling efforts, saving time and providing easy access to otherwise difficult to reach collection sites.

Methods
On days when the Landsat 8 Operational Land Imager (OLI) satellite passed over the researched bodies of water (e.g. Braddock’s Bay, Lake Ontario, Long Pond, and Cranberry Forest, shown in Figure 1), water samples were obtained via kayak or UAV. Water temperature at the site of collection was also recorded. A small-UAV license was obtained before flying the vehicle. The Phantom 3 Drone (DJI) had its return-to-home feature enabled, with max distance disabled and max height set to 100 m. The drone was modified with foam pontoons and surgical tubing as shown in Figure 2. A polyester line measuring ~90cm was attached to a clasp on the surgical tubing used to hold a 50 ml Falcon tube for collection. The drone was calibrated and both sticks were pushed together to start the motors. The device was then piloted to approximately 100m off the shore of the different bodies of water and lowered until the tube submerged. The drone was piloted back to researchers using the on-board camera and the tube was capped before the device was landed. The samples were vacuum filtered through a 0.2µm millipore membrane. Filter membranes were set onto R2A agar and incubated for at least 48 hours. Subcultures were taken until pure cultures were obtained. The pure cultures were stored in a 30% glycerol solution and frozen at -80°C.

Results
The UAV was successful in collecting samples at a much faster rate than that of using a kayak. Samples were obtained from Lake Ontario without the cost or safety hazard associated with boating out to collect samples. A total of 83 water samples in 7 collection dates were obtained, a number only made possible by the use of the UAV. The modification of the vehicle for water collection was simple and inexpensive, and allowed for the use of sterile containers and sample isolation after collection. Samplings at up to 5 sites were possible using the power provided by a single battery. Collection took place in small and large ponds, Inndequoit Bay, the Genesee River and off the coast of Lake Ontario.

Conclusions and future directions
i) The use of a UAV to collect water facilitates sampling from offshore sites.
ii) Sampling may take place, in our experience, at a wide range of distances, from a few meters to close to a quarter of a mile (400m) over water.
iii) The use of the onboard, live-streaming camera facilitates the final (water) approach at distances of more than 100m.
iv) The payload used in our test (~40ml) was easily managed by the UAV, which suggests that larger volumes can potentially be acquired.
v) Use of the UAV reduced the time of collection in half, compared to the use of watercraft.
vi) In some instances, remote link with the UAV was lost at distances of more than 100m; this issue remains unexplained. In these cases, the UAV automatically returns to the launch site.
vii) The final descent for sample collection is not without risks; the UAV is top-heavy, and contact with the water can cause it to flip and crash.
viii) Additional issues to consider during collection are wind strength and loss of line of sight between the pilot and the vehicle.
ix) Future tests will include larger payloads, bridge collection, and waterproofing.

Table 1. Pathogenicity of representative bacteria found in samples analyzed up to date; 938 specimens were isolated from 83 samples collected in 2016, and are yet to be sequenced for species identification.

<table>
<thead>
<tr>
<th>Year</th>
<th>Specimen</th>
<th>Pathogenicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Aeromonas</td>
<td>Human, opportunistic</td>
</tr>
<tr>
<td>2016</td>
<td>Bacillus</td>
<td>Used for pest control</td>
</tr>
<tr>
<td>2016</td>
<td>Comamonas</td>
<td>Plant</td>
</tr>
<tr>
<td>2016</td>
<td>Enterobacter</td>
<td>Human, opportunistic</td>
</tr>
<tr>
<td>2016</td>
<td>Escherichia coli</td>
<td>Pathogenic</td>
</tr>
<tr>
<td>2016</td>
<td>Erwinia</td>
<td>Undetermined</td>
</tr>
<tr>
<td>2016</td>
<td>Pantoea</td>
<td>Undetermined</td>
</tr>
</tbody>
</table>

FIGURES: a) UAV. A Phantom 3 (DJI) drone quadcopter was used. Polyethylene foam was used to build pontoons, with the aim of preventing submersion of the camera during sampling. b) Collection in pond. The UAV was positioned above the collection point and lowered until the tube was submerged and filled. c) Collection device. Tygon tubing was used to build symmetrical holders for the nylon line used to hold a 50 ml Falcon tube. The picture was taken using the UAV camera. Line-streaming to the pilot facilitates the final approach. d) Lake Ontario-Rochester Embayment area. Yellow circles mark the principal UAV-collection sites, while red circles mark other collected sites. Collection (approx. 40m) took place at the surface the body of water. e) Manual collection. Water collection in previous years took place using canoes and kayaks. The use of an UAV saved time and required less equipment, facilitating transport, lowering expenses and allowing for more frequent sampling.

References