Exploring the use of Commercial Off-the-Shelf (COTS) Unmanned Quadcopters to Identify and Characterize Ice Surface Features

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Abstract:

Unmanned Aircraft Systems (UAS) are widely used for inspection, surveying, and mapping applications and data collection in terrestrial-to-coastal-to-oceanic systems. But large UAS systems are complicated and expensive, and require advanced technological expertise for data post-processing. Recent advances in the capabilities of small, affordable, commercial off-the-shelf (COTS) unmanned aerial vehicles (UAVs), such as "drone" quadcopters, have opened up a wide range of possibilities for using COTS UAVs to perform missions and provide data products traditionally reserved for larger, more expensive UAS platforms. Additionally, open source and/or affordable image processing software tools have simplified data post-processing. Small UAV quadcopters have great potential for use in mapping and data collection in polar environments, especially at scales below the resolution of satellite or aircraft remote sensing systems.

Today's COTS UAV quadcopters have not been ruggedized to withstand harsh polar environments but a future application for UAV quadcopters that has great potential in polar science is the identification and characterization of small scale sea (and land) ice surface features such as ridges, snow drifts, cracks, leads, and rubble fields. In this study, processed imagery collected by COTS UAV quadcopters during test surveys will be presented to evaluate the current potential for using COTS UAVs to identify and describe surface features over ice.

Preliminary results suggest that current COTS UAV platforms can provide imagery of sufficient resolution to identify and even measure larger features over ice (e.g. sea ice pressure ridges), but are still limited in their ability to identify and quantify finer-scale surface roughness features. The results, however, suggest future potential for COTS UAV deployment in polar research/operations as these platforms become more advanced in terms of control systems, power sources, sensor system integration, increased payload, and more ruggedized designs for employment in harsh environments.

Opportunities and Challenges:

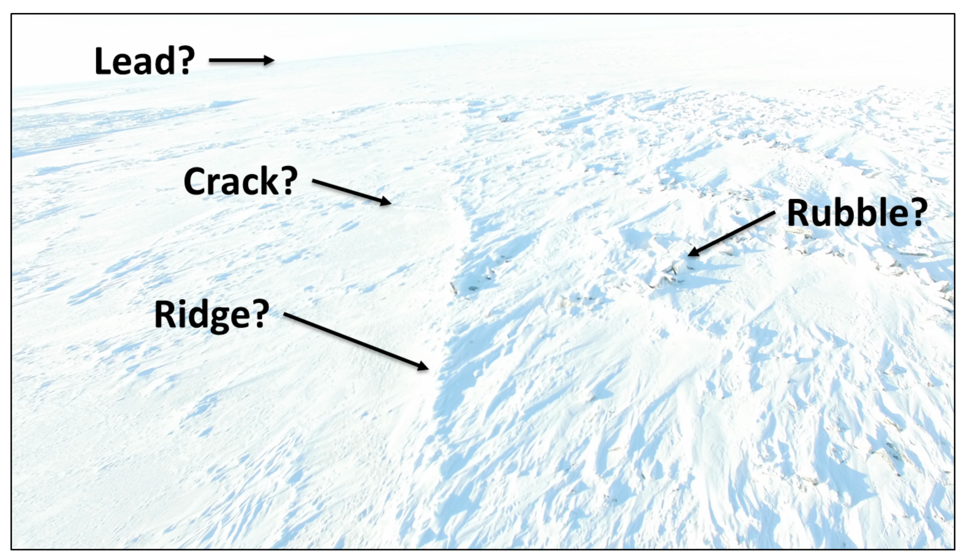


Figure 1. Aerial COTS UAV photo taken roughly 60 meters over a fast sea ice survey site in Barrow, Alaska in March. 2015.

Operating UAV systems, especially those not engineered for arctic environments, pose many challenges specifically operating time, picture clearness, and GPS accuracy. Due to the extreme environment, the lithium-ion batteries are subjected to extremely low temperatures within the poorly insulated body of the COTS UAV. These temperatures adversely impact the battery life, sometimes cutting operation time from 30 minutes to < 10 minutes. In **Figure 1** the reflectivity of the snow is shown washing out the camera. While polarized camera lens can help the light issues, point cloud generation for surveying and mapping is directly dependent on picture resolution. The on-board GPS does not have enough precision for high-resolution object analysis and surface surveying and mapping. Due to the high arctic latitudes poor GPS signal connectivity is an obstacle as well even for post-processing. The GPS issues become even more challenging when performing mapping, surveys, and object identification on drifting sea ice.

DJI Phantom 3 Professional Quadcopter 4K UHD Video Camera Drone

Conceptual Approach:

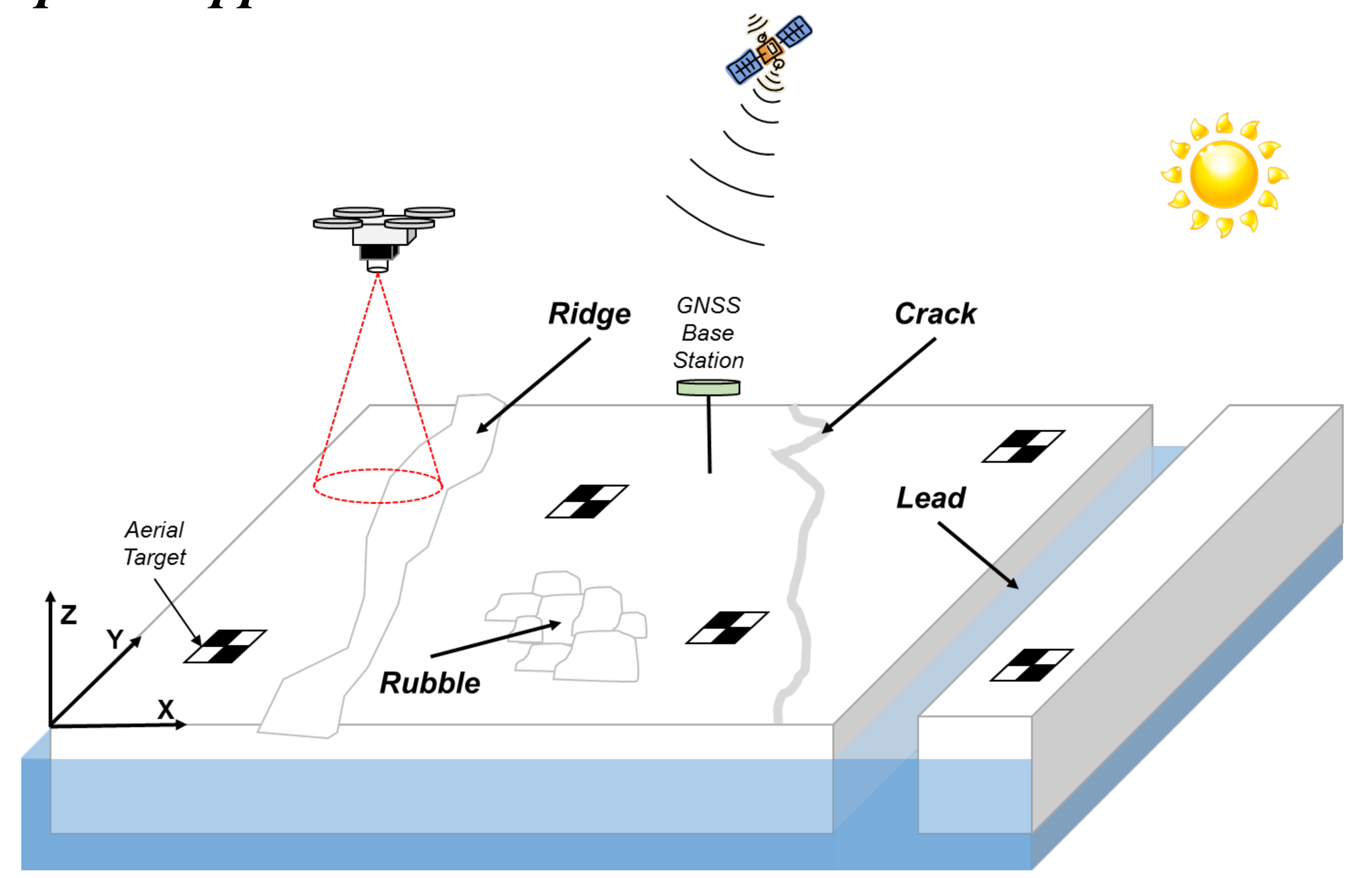
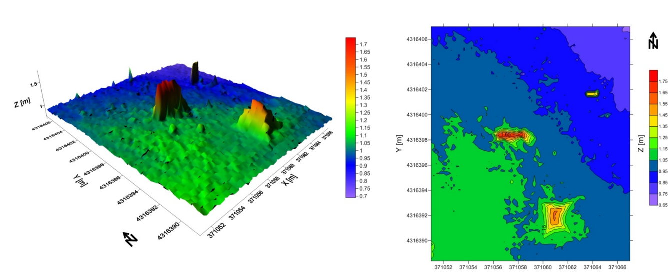


Figure 2. Concept of a typical arctic sea ice environment that COTS UAS systems will operate and survey autonomously. The features (crack, sea ice lead, and pressure ridge) are all objects of interest that can be characterized, scaled, and analyzed using the COTS UAS.

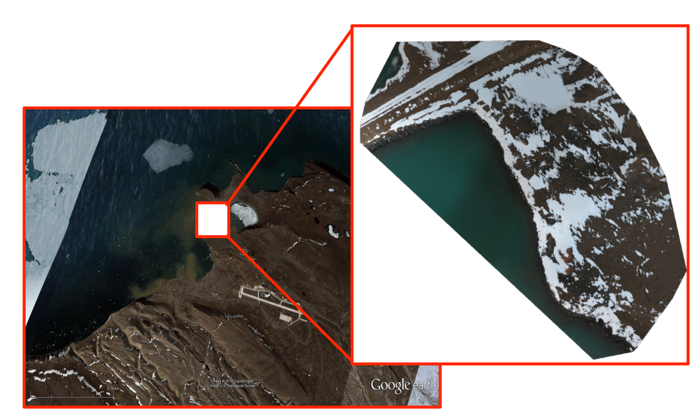
By utilizing the on-board high definition camera, a COTS UAV systems can potentially analyze ice characteristics, identify features, produce surface topography maps, and scale larger objects. The COTS UAVs operate at altitudes lower than aircraft and satellite capabilities, typically 40-80 meters, and can offer timely ice analysis. The use of affordable (or even freeware) software for photogrammic analysis, widely used for agricultural applications, allows photos collected on autonomous COTS UAV missions to be used to ultimately produce a point cloud of the surface surveyed. The point cloud generated from high definition still photos can be port-processed in conjunction with a high-precision GNSS network to map the topography of a survey area. Digital surface elevation maps, orthomosiacs, and specific object scaling from the COTS UAV's photos will allow for ice feature analysis and surface characterization (**Fig. 2**)

Step 1: Establish Arctic flight feasibility with DJI Phantom 3 Professional in Barrow, Alaska. High definition still photos and video were captured and analyzed.

Step 2: Simulated ice survey site on U.S. Naval Academy campus (DEC 2016). Survey flights used a combination of gridded and circular flight paths at different altitudes.



Step 3: Sea ice survey, Thule AB, Greenland with GNSS support and multiple aerial survey days.



Step 4: Post-process sea ice survey data for high-resolution (< 5 cm) ice-field surface mapping and analysis.

Preliminary Results:

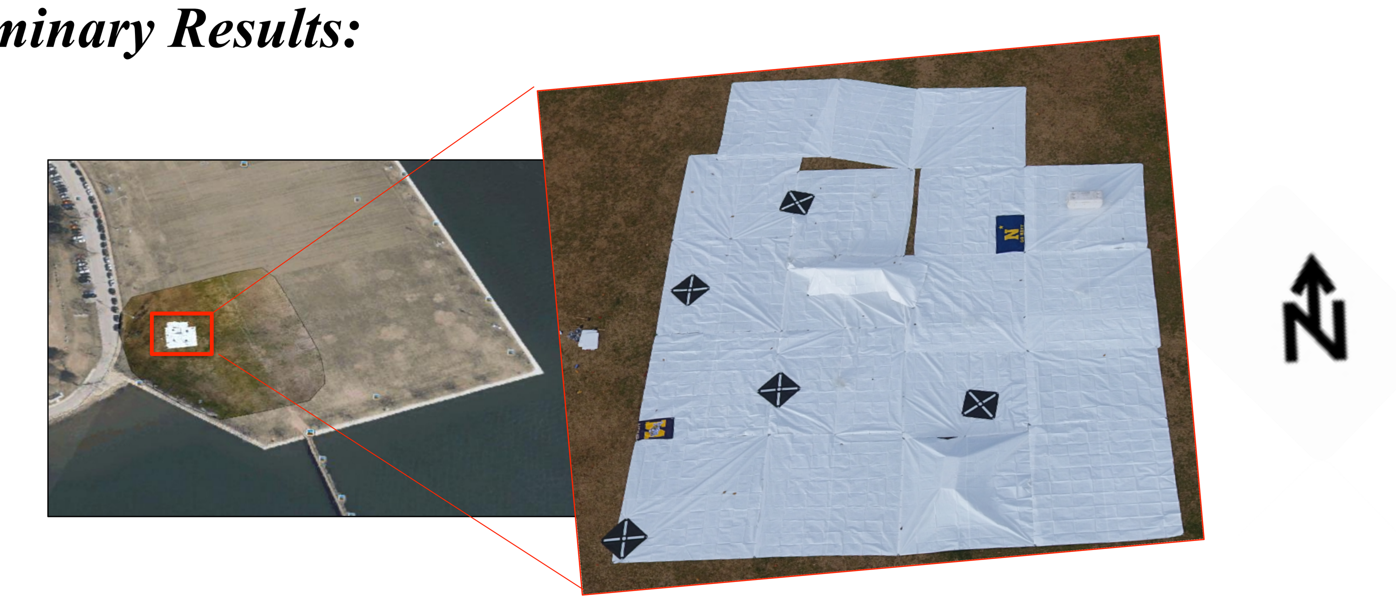


Figure 3. Simulated ice field at U.S. Naval Academy including ridges, ice blocks, cracks, and featureless terrain surveyed on 01 DEC 2016. The black squares are Ground Control Points (GCP) which are recognized from one photo to the next and increase surface mapping accuracy.

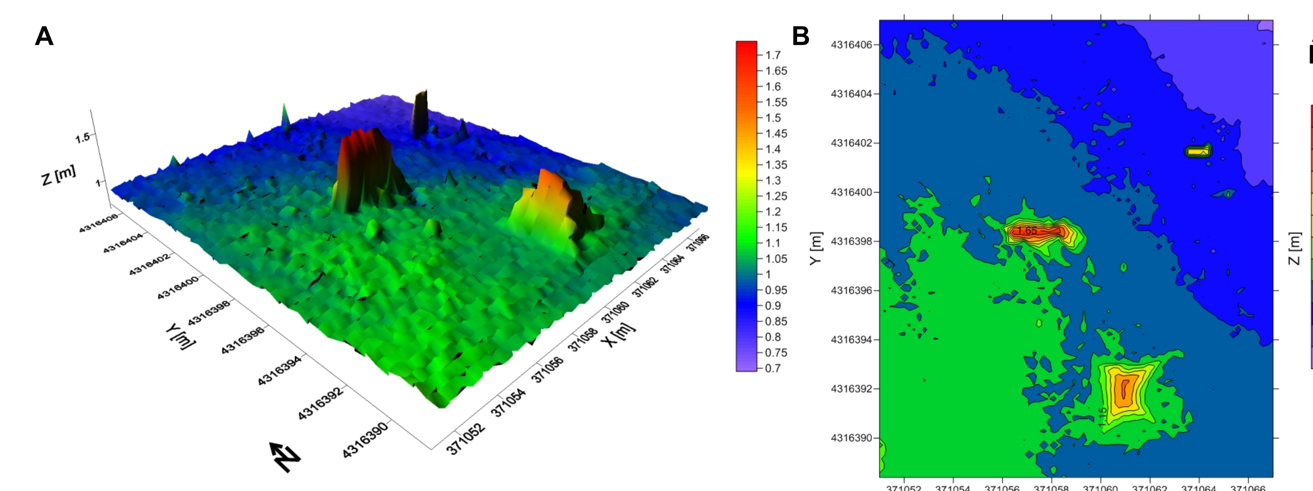


Figure 4. **(A)** 3-Dimensional surface map of simulated ice field in Annapolis, MD on 01 DEC 2016. **(B)** Contour map of simulated ice field in Annapolis, MD on 01 DEC 2016.

An site survey over a simulated ice field (**Fig. 3**; with ridges, ice blocks, rubble, and leads) demonstrated the capability to resolve topography and features. The surface map and 2D contour map (**Fig. 4 A&B**) show that the point cloud resolved from the aerial still photos is dense enough to produce a topographic product with minimal post processing. The point clouds was produced from a circular flight path capturing 140 images at an altitude of 20 meters. However, the minimally post-processed data overestimates the objects heights. Vertical resolution should be improved in the future with high-precision geo-location data.

Future Work:

Figure 5. Survey site in Thule AFB, Greenland (September 2015).

- ***Sea-ice surveys will be conducted at Thule Air Base, Greenland in March 2017 as part of the USNA Polar Science & Technology Program (PS&TP)/NASA Operation IceBridge field research experiment (Fig. 5)***
- ***COTS UAV data collection will focus on identifying dynamic snow and ice features***
- ***Data collected will be post-processed with the integration of high resolution GNSS data***

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