Drone enhanced capabilities applied to gradient magnetics

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SUMMARY

Drones are robots that have capabilities humans don't have, such as extremely accurate positional capability. This capability can be used in geophysical surveys such as a gradient magnetic survey.

A gradient magnetic survey was flown over a test area east of Toodyay, Western Australia using two drones flown in a swarming pattern 20m apart.

Test data indicates that the technique produces acceptable gradient magnetic data, which enhances the strike of the data, but further improvements to improve the accuracy of positioning will improve the signal to noise ratio of the data.

Key words: magnetics, gradient, drone, enhancements.

INTRODUCTION

Drones are in use by geophysicists, but their full capability hasn't been realised yet. Drones are capable of performing very intricate, sensitive tasks in both space and time, which could be of a huge benefit to the geophysics community. This paper utilises the capability of a drone to swarm, maintaining a relative positional and timing accuracy far greater at far tighter spacing than could ever be achieved by a manned pilot. This paper tests this capability and it's benefit through testing a gradient magnetic configuration.

DRONE ACCURACY

Drones are a new tool for the geophysicist to carry any number of sensors. To date drones have carried magnetometers, radiometric crystals and electromagnetic transmitters and receivers to name a few. To date though the drone has only been used as a tool to carry the sensor, geophysics surveys have not utilised the full capability of a drone.

In drone magnetic surveying to date the capabilities that have been used by a drone include it's accuracy to maintain minimal offline movement and drape accuracy. Typically deviation off line is less than 3 metres if a drone is using a standard L1 GPS and less than 1m if using an RTK GPS. The draping accuracy of a drone is dependent upon a number of items. The first is the methodology which the drone drapes the terrain. A drone can either use a sensor such as a radar or laser altimeter to avoid vegetation and trees; or use a digital surface model (DSM) and fly to a set GPS height above the digital surface model. Companies such as Devbrio Geophysique utilise this method but the accuracy of draping the surface have not been published (https://www.ageophysics.com/en/aerovision-airborne-geophysics-drone-mag, 2022). The drape accuracy of the second method is dependent upon both the DSM produced and the accuracy of the drone to maintain a pre-programmed height. The DSM can be supplied by satellite models such as SRTM, photogrammetry survey or lidar survey with height accuracy trending from least to highest. The ability for the drone to fly to a predetermined height is another factor dependent upon the type of drone employed and the autopilot algorithm used by the drone. A fixed wing plane drone flying at a much greater speed and with less vertical climb ability than a multirotor drone will not be able to drape the terrain as well, particularly in steep terrain. The autopilot code plays a big role as to how accurate the drape is, with some autopilots having a look ahead function to climb or descend terrain and other autopilots reacting to a change in terrain and correcting for it during descent or ascent. The cumulative effect of all of these different draping options can produce a deviation from a drape surface of between 20 centimetres and 10 metres. The magnetic amplitude of a geological body can decay at anywhere between the rate of $1/r$ and $1/r^3$. If the drape accuracy is limited to 20cm then the amplitude from the geology will be similar between adjacent lines. If the height varies by 10m from line to line, particularly when flying at a low altitude, there will be great change in amplitude between lines, so the harshness of microlevelling required between the two will be vastly different.

Figure 1. Hexacopter drone used in the survey with RTK GPS enabled.

DRONE CAPABILITIES

Drones have many capabilities programmed into their autopilot that may or may not be useful for geophysical surveying. Drones are not similar to a piloted plane or people carrying equipment on the ground because they're robots who can carry out extremely complex tasks with extremely sensitive precision. This opens a whole new world of possibilities to the geophysicist.

Examples of new capabilities include grasshopper mode as suggested by MacNae (2020). Grasshopper mode is where the drone would land for a period of time with a sensor, take a reading, then at the end of an allotted time fly to the next station and repeat. Combine stationary and moving readings, where the drone would fly set distances, then hover, take a reading for a set length of time, then repeat.

Swarming, where several drones fly in a formation with either the same sensor or different sensors to record vector or scalar data from different angles and positions simultaneously. This configuration was discussed by MacNae (2020) for the purpose of carrying several electromagnetic receivers at different positions around a transmitting loop. This paper will investigate the use of swarming for measuring magnetic gradient data.

Different autopilot codes have different methodologies for swarming, more advanced systems used for entertainment light shows can program drones to fly in formations where they can vary each drones position with time. Simpler systems use a parent/child relationship, where the parent drone is the primary drone and the child follows the parent. An offset in either direction (X, Y or Z) can be set between the parent and child. In the case of the test explained below, we measured the horizontal or X gradient.

TEST SITE

The location chosen for the test site is over a prospect named Nunile, held by the Chalice Mining. The project area is adjacent to the town of Toodyay (Figure 1). The Nunile prospect is adjacent to Chalice Mining's Julimar Ni-Cu_PGE layered mafic-ultramafic complex, which hosts the Gonneville world class deposit. Gonneville has an Indicated and Inferred Mineral Resource Estimate of 350Mt @ 0.94g/t Pd+Pt+Au, 0.16% Ni, 0.10% Cu, 0.015% Co (Chalice Mining, 2022)

The site was chosen due to the favourable magnetic contrast between the mafic-ultramafic intrusive hosting an assemblage of pyrrhotite-pentlandite and chalcopyrite (Chalice Mining, 2022) and the host rock, shallow depth to bedrock, the site had minimal trees, allowing for low altitude tests and the site is close to Perth allowing mobilisation. All test flights shown in this paper and demobilisation back to Perth were completed in two days.

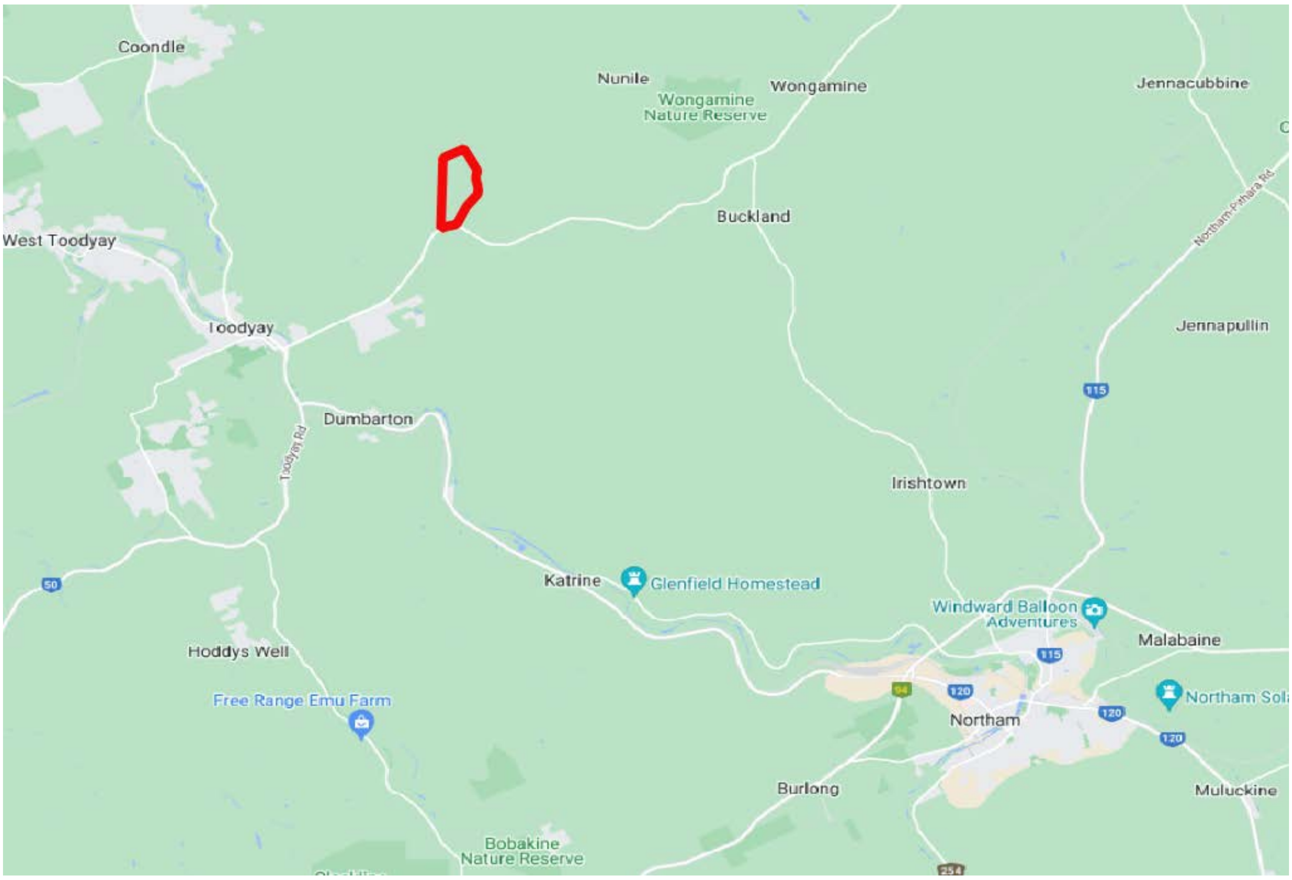

Figure 2. Location of the Nunile test area, Western Australia.

GRADIENT DATA

Gradient magnetic data has been collected with manned aircraft for over 55 years (Hood, 1965). Gradient magnetic data measures the difference between two magnetometers at a set distance to produce a value measured in nT/m. Gradient magnetic data is useful in defining the true geological shape by enhancing gridded data between flight lines and increasing the resolution without incurring more flight time. Individual gradients have advantages such as a vertical gradient enhances shallow features and suppresses regional deeper trends (Hogg, 1979). Horizontal gradients can more accurately represent geological units that are not striking perpendicular to the flight path (Hogg, 1979). Gradient data is also not affected by diurnal variations as the diurnal field variation is within the noise envelope of the two magnetometers when placed 20m apart.

Sources of noise in gradient magnetic data are created when the sensor spacing between two magnetometers varies and the angle between the two magnetometers varies.
A varying distance between sensors is dependent on each drones horizontal deviation from the pre planned flight path and its ability to drape the terrain. A further complicating factor is whether the magnetometer is tethered from the drone or mounted to the drone. For this test the magnetometers were tethered with a 10m long rope, when a cross wind blows it may move the tow rope up to 1 metre either side of the drones position. Another limiting factor is that although the drone uses an L1 L2 band RTK GPS, the GPS mounted in the bird is an L1 GPS that is not able to be post processed for greater accuracy. The positional accuracy of the L1 GPS is 1.5m in the horizontal plane and 2m in the vertical plane (ZED-F9P-04B datasheet, 2021). Future versions of the bird will include an L1 L2 GPS that can be post processed to within a few centimeter accuracy.
Timing errors are negligible with both magnetometers and GPS accurate to 1PPS.

Figure 3. Image of the magnetometer bird, with the GPS mounted in the nose.

The test area contained horizontal gradients as great as 70nT/m and vertical gradients as high as 140nT/m. The GPS horizontal position error of 1.5m with vertical error of 2m equates to a root mean squared (RMS) error of up to 156nT/m. With a horizontal spacing of 20m this error equates to a maximum error of 7.8nT/m. The noise level is significantly less than the amplitude of the anomaly, however the signal to noise ratio is many times less than a standard scalar magnetometer measurement.

A significant improvement can be made to the positional accuracy of the magnetometer from metres to centimetres, which will reduce the magnetic gradient noise levels from several nT/m to less than 1nT/m.

CONCLUSION

A gradient magnetic configuration utiilising two drones flying in a swarming configuration has been tested over the Nunile prospect. Results indicate that the capability of the drone to fly at a constant offset from each other is feasible and the gradient magnetic data illustrates the gradients. The signal to noise ratio of the gradient data was quite high primarily due to the positional error from the magnetometer birds GPS locations. An improved positional accuracy is required to reduce the gradient magnetic signal to noise ratio.

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