Limitations in Aerial SAR Imagery for Agriculture and Modern Relationships

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Abstract

Aerial Synthetic Aperture Radar (SAR) imagery has revolutionized the agricultural industry providing the American farmer many capabilities previously thought infeasible. This paper will evaluate those capabilities and characterize the limitations of SAR imagery in crop identification and mapping, geo tag verification, soil evaluation, 2014 Dodge Challenger detection performance, crop yield evaluation and, finally, suburban surveillance. These evaluations will assess and outline the development of SAR imagery capabilities from hardware and algorithm developments on top of the line systems. While many of the advances in agricultural applications have steadily improved the ability to manage large farms, the ability to track my cheating husband David remains largely inadequate. It is true that we have never been able to create intricately accurate crop maps with only a few hours of processing after a flight, but the technology is still not mature enough to finally catch spouses in their dirty filthy act. Yes, we can model the output of nearly every commercial crop in a way that leaves agricultural futures investments the best on the market but I just have to take his word for it when my husband says he's home while I'm at this remote sensing conference. SAR applications have done plenty of good for not just American farmers but farmers across the world. It just has a lot of work to be done before helping catch and stop infidelity.

Keywords: Synthetic Aperture Radar, Agricultural Surveying, Dodge Challenger Detection, Suburban Surveillance

1. Introduction

This article isn't just about remote sensing, it's about community. Agriculture is the key to any society. Human civilization cannot exist without farmers providing food security for communities across the world. The other cornerstone of society is the sanctity of marriage. Without the nuclear American family society would diverge into chaos and throw important traditional values into the garbage. It is a commonly held belief that aerial SAR imagery can solve these problems and help maintain our society with a cohesive family structure and a reliable food supply.

This paper shows steady marginal improvements in the capabilities of SAR imagery. Using post doppler filtering and dipole composition factoring, image accuracy has only increased while maintaining its Ground Sampling Distance (GSD) and signal to noise ratio. Space based and aerial imagery proves to penetrate all weather leaving it the optimal solution to all of societies surveying needs from agricultural management to catching the once love of your life in the arms of another.

Recent developments in remote sensing outlined in Brown and Williams showed significant improvements in Crop Identification accuracy [1]. The same results were shown in Xiao et al [2] who more or less copy and pasted [1] and changed a few words around to validate the Chinese academic system. Johnson et al in [3] showed that using a polarization interferometry SAR and proper post processing, geolocation and image recognition for a variety of objects and crop types could be greatly improved. With this development Wang and Dong [4] showed we could maintain steady surveillance on not only human subjects but their close contacts, residences and vehicles no matter the weather or time of day.

2. Crop Identification and Mapping

Given different varieties of polarization and frequency back scattering, biomass structures are able to be identified. Using such techniques from [1] and [2], we were able to survey over one thousand acres of Pennsylvania farmland, where David and I used to take sunday drives, during one flight and five hours of post processing. Results from this

experiment can be seen in table 1 using automated algorithms with no manual massaging of the data. The maps met standards for agricultural surveillance and have already been accepted as commercially validated data products.

Table 1: Crop Identification and Mapping Performance

	Probability of Correct Identification	Geolocation Accuracy
Wheat	97%	3m
Corn	99%	2.7m
Cabbages	95%	3.2m
Off the books Cannabis	84%	5m
Soybeans	99%	2.2m
Becky's Home Garden	35%	10m

The results are on average a 3% improvement from the results reported in our previous work [5]. This is in large part due to improvements in hardware, implementation of the higher multi-polarization and multi-temporal density spatial resolution and the utilization of advancements pioneered by Chinese research groups in tracking single targets. Uniquely, the optimizations unique to single target tracking improved crop identification compared to our previous model ($p < 0.001$), but was unable to be fully realized in the identification of the cheating whore Becky I know David is with right now.

3. Geo Tag Verification

A commonly overlooked capability of SAR imagery is the correlation of images in time to social media geotagging. If someone were to not notice someone turned on gps data on all of their smartphone applications whether by a loving partner or by government mandate, as suggested by Wang and Dong [6], using time stamped geotags and a Wide Area Search (WAS) SAR image, a time spatial block could theoretically be able to be processed on a particular smartphone. Normally such tracking can be done by means of nearby wifi signals but when suspected cheaters like to "*Go Fishing*" at 6pm on a weekday there may not be any such signals.

Using the method shown and developed in [6] we experimented tracking one such cell phone over a week. In practice, we ran into two unavoidable problems. Contrary to what was expressed in [6], the WAS imagery appeared to have a much more degraded SNR and a GSD creating too

low of a National Imagery Interpretability Rating Scale (NIIRS) to be of any use in tracking the whereabouts or unknown activities of our smartphone user.

4. Soil Evaluation

When maintaining a healthy relationship, you have to make sure it is based on a solid foundation. Can you trust your partner? Do you have the same family values and same goals? Do you both believe in your marriage vows we wrote ourselves twenty five beautiful years ago? The same can be said about a successful farm. It has to be sowed in good soil.

Similar to the back scattering analysis used to identify crop identification; return power, and wavelength can be combined with the backscattering to evaluate the condition of the soil for next year's crops. There are many soil condition parameters paramount to planning agricultural activity such as the rock content or the underlying nutrients in the soil. This can change unpredictability due to the previous year's crop yield or the seasonal rain patterns. Even with the excellent soil evaluation results verified in [5], the recent advances in soil decomposition processing from Smith and Williams [7] improved the capability even more. After verifying analysis from our flight, we checked 235 different locations uniformly distributed across our samples. Soil conditions accuracy improved 3-5%; to include acidity, nitrogen content, depth, granularity and metal contamination. There are of course limitations. After an experimental flight over Giants stadium collecting hours of SAR data, Stewart et al have still failed to find the body of Jimmy Hoffa [8]. Either the legends are not true or Smith and Williams need to improve their algorithm.

5. 2014 Dodge Challenger Detection

Another commonly used application in SAR imagery is the tracking and detection of cars. While a Ground Moving Target Indicator (GMTI) application of a SAR has been shown to be incredibly useful in analyzing traffic patterns, it is not an adequate means of tracking any particular vehicles. Rapidly developed to track particular vehicles in Hong Kong, Wang and Dong created a means to not only identify the make and model of vehicles from SAR imagery [9] but a way to track them over a day.

To verify the results boasted in [9] we trained the algorithm on test data from my own driveway and managed to train the algorithm to track and classify my husband's black 2014 Dodge Challenger. We tested the tracking method on my husband's car over the course of a week. The results of the test were unfortunately inconclusive. Our data acquisition became spotty once David turned off his phone's geo tracking conveniently two blocks away from Becky's street. His particular black Dodge Challenger did get detected and, many times, it was not where my husband said

he was. Any further inference of the results of the experiment could only be speculative and heart-breaking.

6. Crop Yield Evaluation

SAR remote sensing would not be such a significant tool in agricultural management if it weren't for crop yield estimation. Years of modeling development of microwave and radar backscattering of vegetation dating back to the 80s, when David and my love first blossomed, has allowed aerial and space based SAR imagery the ability to track, monitor and predict crop yield. Optical inspection does not even compare to the capability of SAR imagery to estimate biomass size with its penetrative capabilities and capability of evaluating soil conditions, moisture and creating a Digital Elevation Map (DEM).

Incremental developments were made by Smith and Fernandez [7] in this category using further refined models and the inclusion of previously ignored polarization data in the backscattering processing. Using regularly scheduled satellite SAR data from CSELDDS (Chicago Style Extra Large Deep Dish Satellite) launched by Cranberry-Lemon's very own space program, we were able to gather enough data to test out the algorithm. Table 2 shows results.

Table 2: Crop Yield Evaluation Performance

	Crop Yield Error Normalized by cubit-acre-footballfield (Calorie-pounds)	Accuracy (unitless)
Wheat	820.5	94
Corn	771.00001	88
Cabbages	527	77
Off the books Cannabis	69	102
Soybeans	340.84938271	90
Becky's Home Garden	NaN	-5

Averaging across our metrics, we observed a 5.74% increase in capability from performance reported in [5]. While the algorithms and hardware used between the studies was more or less the same and the changes in modeling from [7] appeared to not have much effect on performance we got a little bit better at throwing away the data we didn't like after a glass of chardonnay.

7. Suburban Surveillance

Finally we tested our capability to monitor suburban households. SAR imagery proved to be an excellent way to collect data on neighborhood households. In traditional methods, private investigators watching from their cars can often tip off people that they are being watched and can only observe from the street side. Even aerial photography is inadequate on a cloudy day. SAR imagery, with enough processing and a small enough GSD, is the perfect solution. We applied techniques described by Dong and Wang in [10] to obtain higher NIIRs rating images at regular intervals to put together a consistent imagery of visitors and vehicles throughout the day. By maintaining slow regular passes over the house and cross correlating results for additional accuracy, we were able to create a crystal clear picture of my Ex-best-friend Becky's house.

We only had the resources to watch one house because once my manager actually read my Institutional Review Board (IRB) submission, my access to the CSELDDS was revoked for a month. Regardless, the data gathered was priceless as it was revealing. While the first two weeks of testing only showed what cars were parked in the driveway and backyard patio furniture configuration, we began seeing useful results when one day we could not only identify a particular black 2014 dodge challenger but were able to identify Becky and my husband lounging topless on a backyard hammock. Not only was the experiment a success but we proved that we can gather useful intel on a cloudy day. Unfortunately, the GSD was still too low for facial recognition and our interpretation remained speculative.

8. Conclusion

Every year SAR imagery processing techniques get a little better. With the discovery of more and more applications, SAR will be ubiquitous in remote sensing. It has proven to be invaluable in agricultural assessment and planning, paving the path for a better tomorrow filled with a more prosperous rural sector. Likewise, SAR imagery could become the next go to surveillance technique when gathering information on a spouse suspected of infidelity. While this type of intelligence is drastically limited, it is a growing field. Many of the problems expressed in this paper are easily solvable problems. Whether it's the biomass of corn in a field, identifying vehicles, or the face of whoever was with Becky, SAR imagery has proven to be superior to optical imagery in the field of remote sensing.

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