Chapter 10
Compute-Efficient Geo-Localization of Targets From UAV Videos:
Real-Time Processing in Unknown Territory

Deendayal Kushwaha
Defence R&D Organisation, India

Sridhar Janagam
Defence R&D Organisation, India

Neeta Trivedi
Defence R&D Organisation, India

ABSTRACT

Unmanned Air Vehicles (UAVs) have crucial roles to play in traditional warfare, asymmetric conflicts, and also civilian applications such as search and rescue operations. Though satellites provide extensive coverage and capabilities crucial to many remote sensing tasks, UAVs have distinct edge over satellites in dynamic situations due to shorter revisit times and desired area/time coverage. The course, speed and altitude of a UAV can be dynamically altered, details of an activity of interest monitored by loitering over the area as desired. A fundamental requirement in most UAV operations is to find geo-coordinates of an object in the captured image. Most small, low-cost UAVs use low-cost, less accurate sensors. Matching with pre-registered images may not be possible in areas with low details or in emergency situations where terrain may have undergone severe sudden changes. In these situations that demand near real-time results and wider coverage, it is often enough to provide approximate results as long as bounds on accuracies can be established. Even when image registration is possible, it can benefit from these bounds to reduce search space thereby saving execution time. The prime contributions of this paper are computation of location of target anywhere in the image even at larger slant ranges, optimized algorithm to compute terrain elevation at target point, and use of visual simulation tool to validate the model. Analysis from simulation and results from real UAV flights are presented.

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INTRODUCTION

Unmanned aerial vehicles (UAVs) are increasingly being recognized as capability multipliers in both military and civil settings. They play crucial role in Intelligence, Surveillance, Target Acquisition, and Reconnaissance missions of the military and are also of great assistance in disaster recovery missions. They carry daylight TV and/or infrared sensors, usually in a stabilized steerable turret or gimbal. Though satellites provide extensive coverage and capabilities crucial to many remote sensing tasks, UAVs have distinct edge over satellites in dynamic situations due to shorter revisit times and desired area/time coverage. The course, speed and altitude of a UAV can be dynamically altered, details of an activity of interest monitored by loitering over the area as desired. Most real-life missions require geo-coordinates of objects on the video captured through UAV. Military may want it to eliminate a potential threat; disaster recovery team may want it to plan the recovery. The results must pass the spatio-temporal accuracy tests; precise efforts must be delivered to a specific location in short time, so as to avoid attacking a target that has moved, minimizing collateral damage, or sending rescue team to a place where it is no longer needed.

Computing the geo-location involves performing series of transformations (Barber, Redding, McLain, Beard, & Taylor, 2006) across reference frames using position and attitude data of the UAV, and the azimuth and elevation angles of the turret. However, all sensors come with inherent inaccuracies. Also, flat or declining military budgets and requirement to keep the UAVs more affordable for civilian applications motivates using low-cost sensors, which obviously are more inaccurate.

Geographical Information Systems (GIS) that store huge amounts of geo-spatial data provide some means for compensating for the sensor errors. The image captured through the UAV can be registered with a pre-registered image to enhance accuracy (Conte, Hempel, Rudol, Lundström, Duranti, Wzorek & Doherty, 2008; Conte, Rudol, Wzorek, Petitti, Iocchi, & Doherty, 2008; Sim, Jeong, Lee, Parkm, & Kim, 1999) . However, in places where there are not many details on the terrain, or on sea, this method is of little help. Further, in disasters like flood, earthquake, tsunami etc., terrain may have undergone substantial changes in the areas of interest and hence registration may fail.

Given these constraints, it is required to have a comprehensive base geometrical model for calculating geo-location from sensor data, prove its correctness under zero errors and prove bounds on accuracies under different error conditions. The accuracy bounds help the users to plan for the worst-case response. The bounds are also helpful in reducing the search space for image registration where possible. Since registration is a highly computation-intensive task, reducing search space is a very attractive option.

This paper discusses a model for obtaining geo-location for a target in real time from UAV videos, taking into account the digital elevation data as well. The novelty of the approach lies in the usage of the combination all parameters and terrain elevation data to calculate target coordinates at the center as well as off the center location of the image. Note that under non-zero, especially under high roll and pitch conditions, the image may represent an arbitrary quadrilateral and off-center calculations may not be trivial. The prime contributions are computations for location of off-center targets, optimized algorithm to compute intersection of the sensor Line of Sight with terrain at target location and use of a visual simulation tool to provide accuracy bounds. Results from real flights of a tactical UAV with specific sensor inaccuracies are also presented.