StagGCP: A Metashape Plugin for Using STag as Robust Ground Control Points for In-field Agricultural Aerial Surveys

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Abstract

As an essential step for most agricultural aerial surveys, setting up ground control points (GCPs) properly enhances photo alignment and the calibration of shifts in time-series scans. However, traditional circular markers provided by Metashape suffer from recognition errors under challenging field conditions and environmental factors, including varying illumination and vegetation occlusion. To address these issues, this study implements a robust marker system named STag to replace the build-in circular markers. To maximize recognition efficiency, the YOLOv11 detection model and SAHI small object detection enhancing framework, trained using synthetic dataset automatically generated from formal field data with circular markers, was implemented to first detect the bounding box of STag markers. Only the bounding box regions were processed for the identification of STag IDs to save the computation resources. The workflow was implemented as a plugin module called StagGCP for Metashape, to make installation and usage easier. Field validation experiments demonstrated that StagGCP achieves stable recognition when marker lengths exceed 40 pixels in both RGB and multi-spectral images. Nonetheless, further practical validation in diverse field scenarios is necessary to refine and validate the robustness of the proposed workflow.

Keyword

Deep learning, Photogrammetry, Structure from Motion, Agisoft Metashape, 3D reconstruction.

Introduction

Using aerial photogrammetry techniques, such as Structure from Motion (SfM), to generate field maps for crop monitoring and phenotypic analysis has become a fundamental practice in smart agriculture. However, the repetitive patterns within crop canopies and their movement caused by wind, as well as reflections on the water surface in paddy fields, challenged the camera alignment stage, which relies on feature point matching. Establishing ground control points (GCPs) as reliable feature pairs significantly enhances the accuracy and success of image alignment. Additionally, GCPs can serve as a reference for calibrating maps across multiple time scans. This step is critical since slight shifts may still occur, even when using real-time kinematic (RTK) devices for georeferencing.

Most photogrammetry software provides features for automatically detecting pre-placed markers in the field. For instance, Pix4DMapper (Lausanne, Switzerland) supports the detection of square and diagonal markers (**Fig. 1a**) while Metashape (Agisoft LLC, St. Petersburg, Russia) detects circular targets (**Fig. 1b**). However, these markers struggle to perform well when partially occluded by weeds or crop canopies.

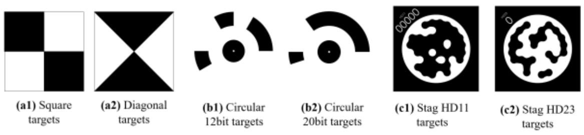


Fig. 1 Examples of non-coded (a) and coded targets (b-c)

To enhance the occlusion tolerance, Benligiray et al., (2019) proposed the STag marker system (**Fig. 1c**), which showed superior performance. However, several challenges remain in applying this system directly to real-world conditions. First, aerial images captured under natural field conditions are highly complex, with crop canopy patterns sometimes causing misrecognition. Second, in high-resolution images, the small size of the marker objects can make detection challenging and may lead to inefficiencies, as unnecessary computation is wasted on irrelevant background details. Third, training an object detection model capable of handling varying natural conditions requires a large amount of diverse training data, which can be difficult to collect and prepare. Lastly, Metashape does not natively support STag markers, meaning that a user-friendly plugin is necessary to integrate STag into the photogrammetry workflow efficiently.

Methods and Results

In this study, we developed a Metashape plugin with a user-friendly interface (**Fig. 2**), named StagGCP, to address the challenges previously described. This plugin module consists of the following key features:

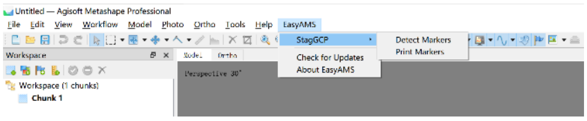


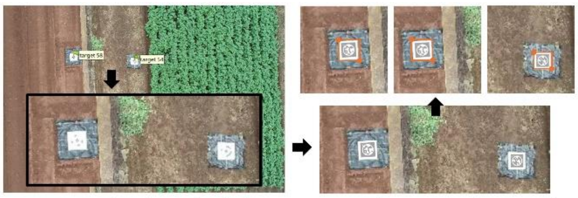
Fig. 2 Metashape UI of StagGCP plugin.

1) The YOLOv11 model, combined with the SAHI framework (Akyon et al., 2022), was implemented to detect small STag markers within high-resolution images (**Fig. 3**).

Fig. 3 YOLOv11 and SAHI detection results on small targets.

2) The STag recognition algorithm is applied exclusively to these detected regions, reducing the risk of misrecognition and optimizing computational efficiency.

3) To train a robust detection model, an automated synthetic dataset generation method was devised, relying on formal field data containing circular markers (**Fig. 4**). This method eliminates the need for extensive manual data collection and preparation.



(a) Metashape detected coded markers in formal studies

(b) Random pasted and processed Stag markers as training data

Fig. 4 Synthetic training dataset generation by formal studies using circular markers

To validate the effectiveness of the proposed StagGCP workflow, we evaluated the recognition capability of various marker sizes under different distances and sensor types. As illustrated in **Figure 5**, most markers were accurately detected when their size exceeded 40 pixels in length.

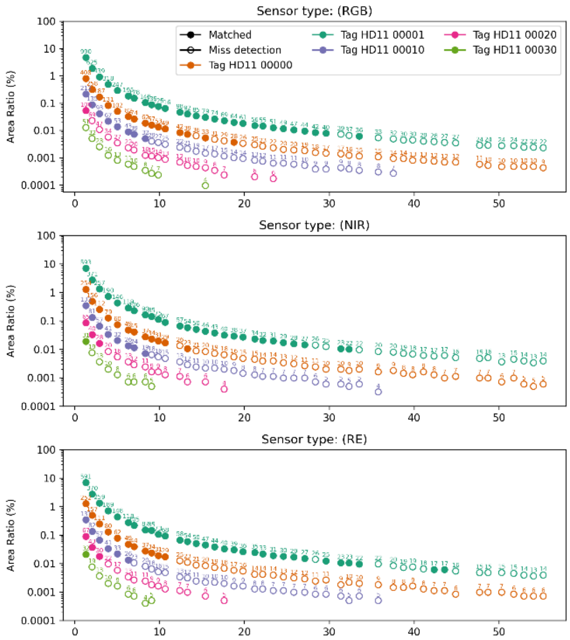


Fig. 5 STag recognition from different distances and marker sizes. Numbers on scatters represent marker pixel edge length.

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