Two-step multi-spectral registration via key-point detector and gradient similarity.

Application to agronomic scenes for proxy-sensing.

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Introduction

Main Question

In agricultural purpose such as precision farming, major mistake are still done in image registration. There is no large study of :

- What is the best spectral band to use as reference ?
- What keypoint extractor algorithms are the most adapted ?

This paper focus on that two question and propose a two step registration:

- affine registration trough calibration and GPS
- perspective correction trough key-point detection
- benchmark of different key-point detector (time/number)
- benchmark for each spectral reference.

Material

Figure 1: AIRPHEN camera

- interferential filter centered at 450/570/675/710/730/850 nm
- focal lens is 8 mm for all wavelength
- raw resolution 1280×960 px with 12 bit of precision.
- internal GPS antenna (3D position)

Data

Two dataset was taken, one for calibration, one for evaluation.

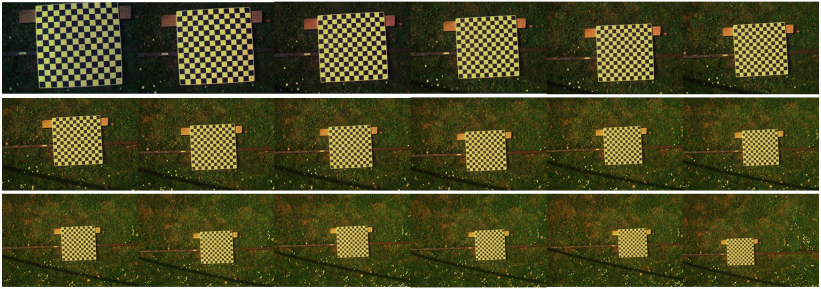


Figure 2: false color reconstruction of each acquisiton height (18) for calibration dataset, from 1.2 to 5 meter.

Methods : Affine correction

Affine Calibration, translation part

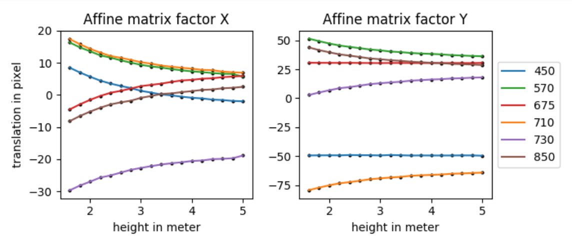


Figure 3: Translation factor from detected chessboard to "virtual" center chessboard at each acquisition height, xmax=30, ymax=77

Affine Calibration, rotation&scale part

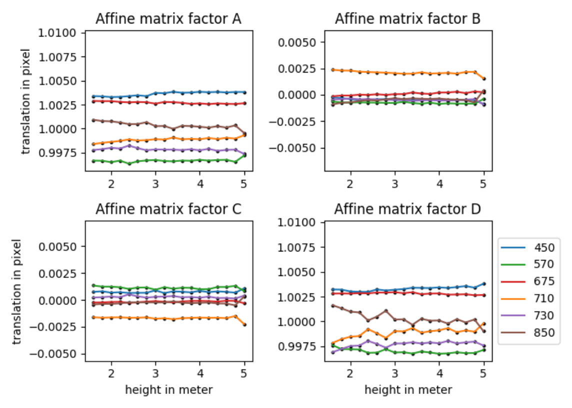


Figure 4: Rotation and scale factor from detected chessboard to "virtual" center chessboard at each acquisition height (precision depend on height but we can notice that these factor are likely invariant)

Affine Correction

From that calibration a affine matrix model are build:

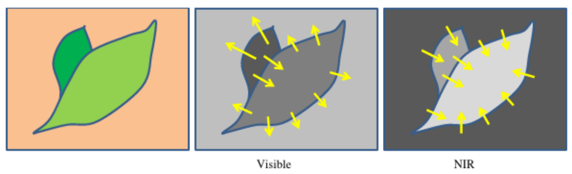
- For X, Y factors an equation are fit for each spectral band [1] and the height from the GPS are used to get the nearest correction
  - $t = \alpha h^3 + \beta h^2 + \theta h + \gamma$
- For A, B, C, D the values at the most accurate height are used

Each spectral band is warped using the corresponding affine transformation. For each spectral band the translation factor are computed from an approximated height given by the GPS. And a crop are applied.

[1] Levenberg-Marquardt with linear least squares regression

Methods : Perspective correction via key-point detector (refinement)

Gradient transform for keypoint detection



To optimize the search of specific keypoint such as gradient break, each spectral band are transformed :

- normalizing using Gaussian blur $I/(G+1)*255$
- gradient is computed with the sum of absolute Sharr filter
- normalization using CLAHE to locally improve their intensity

Keypoint detector (9)

- (ORB) Oriented FAST and Rotated BRIEF
- (AKAZE) Fast explicit diffusion for accelerated features in nonlinear scale spaces
- (KAZE) A novel multi-scale 2D feature detection and description algorithm in nonlinear scale spaces
- (BRISK) Binary robust invariant scalable key-points
- (AGAST) Adaptive and generic corner detection based on the accelerated segment test
- (MSER) maximally stable extremal regions
- (SURF) Speed-Up Robust Features
- (FAST) FAST Algorithm for Corner Detection
- (GFTT) Good Features To Track

Perspective correction via Keypoint

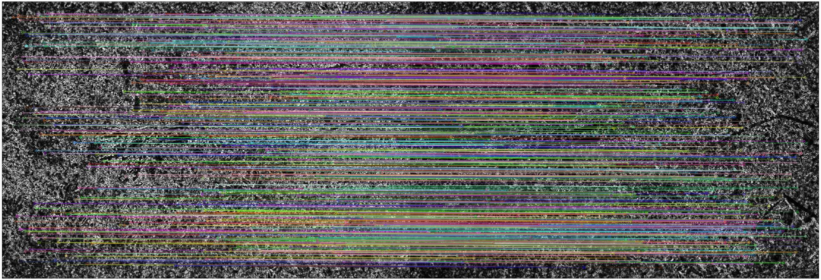


Figure 5: Bruteforce keypoint matching in normalized gradient and filtering (570nm left & 850nm right)

Results

Results : keypoint extractor benchmark

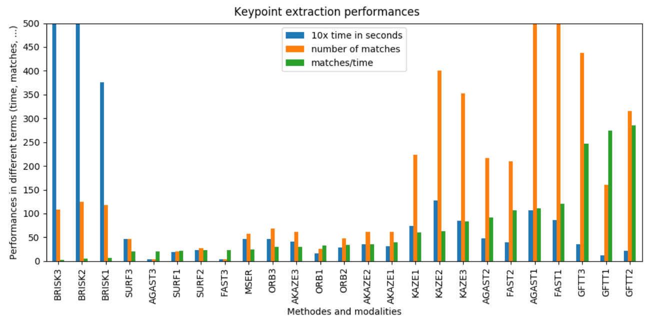


Figure 6: Bruteforce keypoint matching in normalized gradient and filtering (570nm left & 850nm right)

Results : spectral reference benchmark

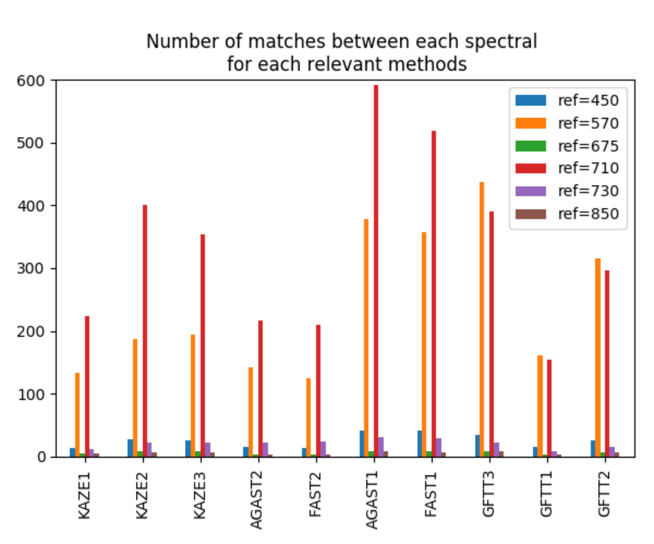


Figure 7: Bruteforce keypoint matching in normalized gradient and

Results : precision

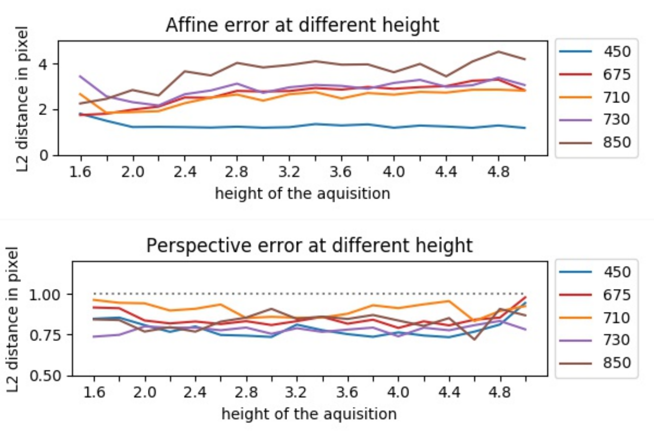


Figure 8: Performance evaluation with 570nm as reference

Conclusion

Conclusion

- This study as determined that the best spectral reference is 570 and 710nm with that hardware. Where major study still define empirically 850nm as registration reference which is largely sub-optimal.
- We have made a large comparison of key-point detector and determined that GFTT are the best key-point detector. Where different study still use ORB and KAZE which is largely sub-optimal (time and precision).

Question ?