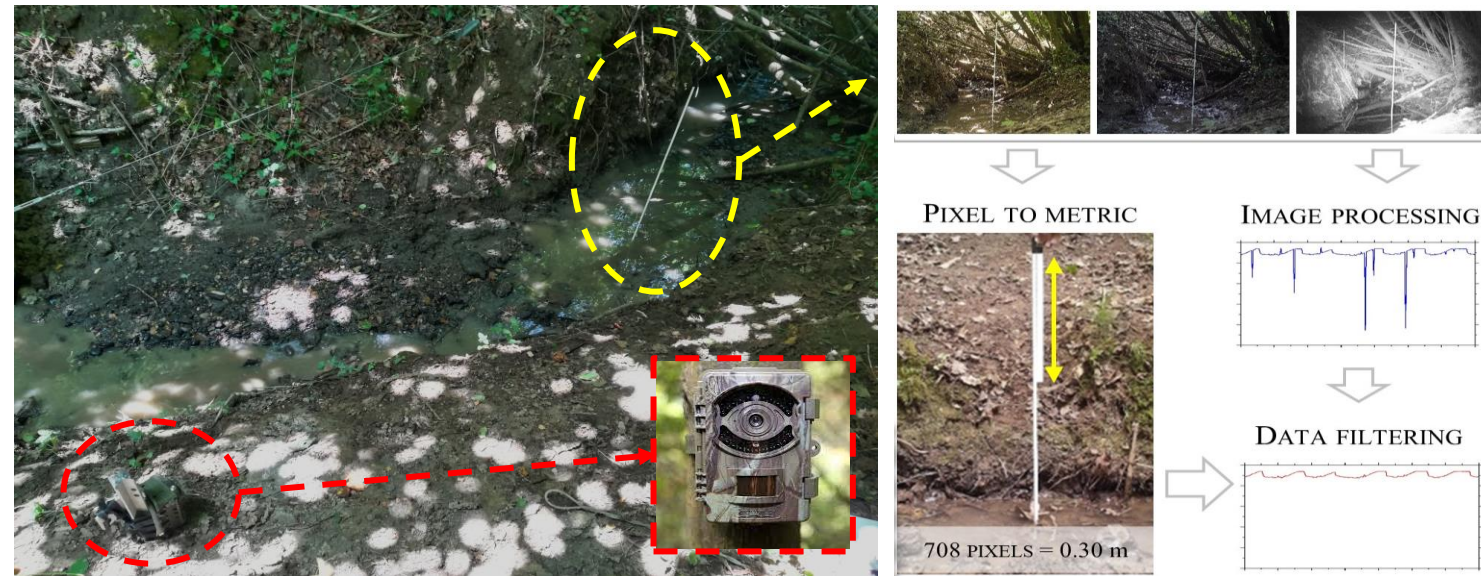


Continuous water level monitoring using time-lapse imagery

Simone Noto, Flavia Tauro, Andrea Petroselli, Ciro Apollonio, Gianluca Botter, and Salvatore Grimaldi

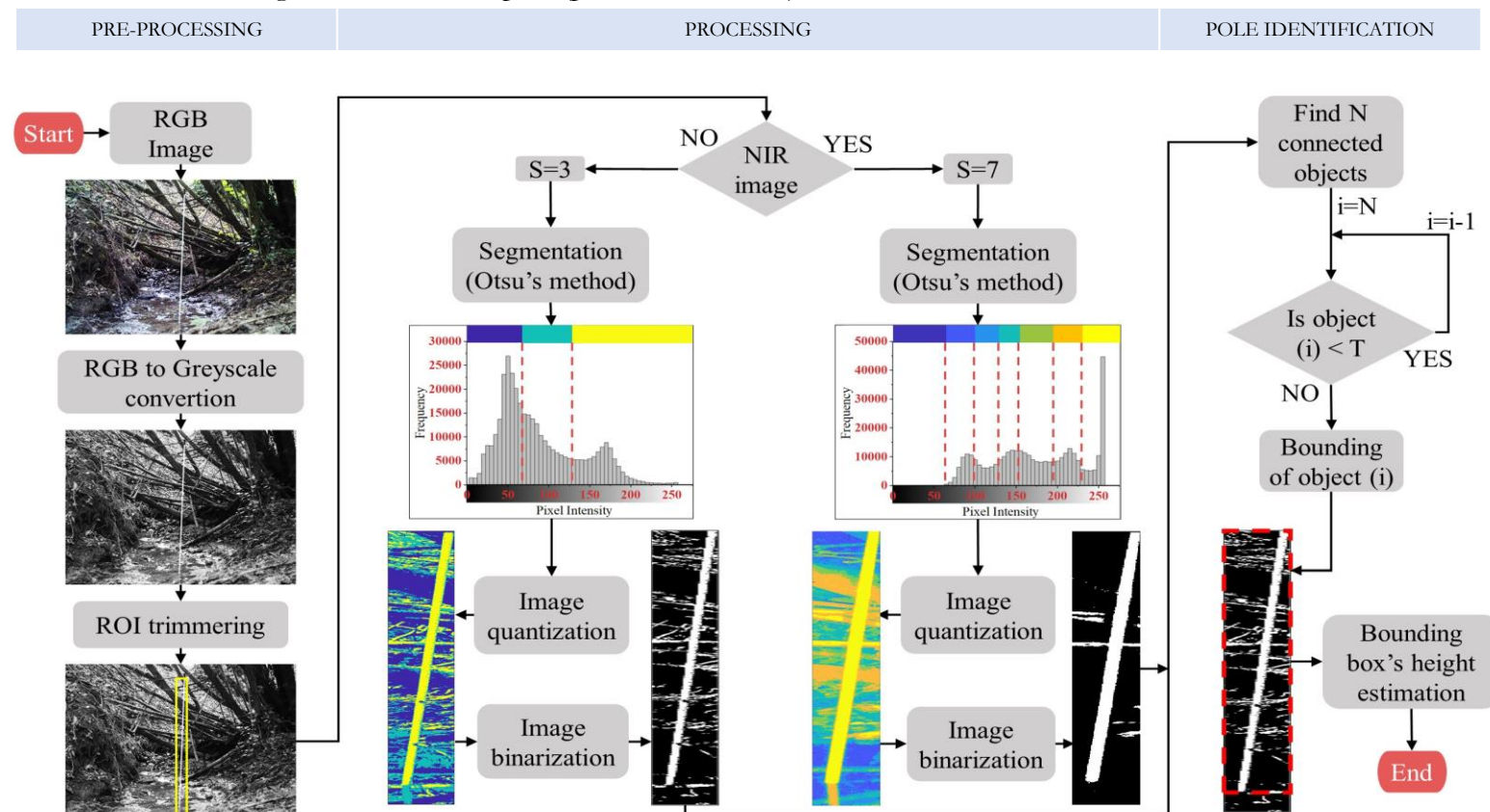
STAGE-CAMERA SYSTEM



Left, stage-camera system including a wildlife camera (enclosed in the red dashed circle) and a white-painted steel pole (enclosed in the yellow dashed ellipse). Right, images are captured both during the day and at night (NIR). Grayscale images are segmented and binarized to detect the pole. Then, a filtering procedure removes eventual outliers. Pixel to metric conversion is conducted by preliminarily calibrating images in situ based on the pole length.

IMAGE PROCESSING

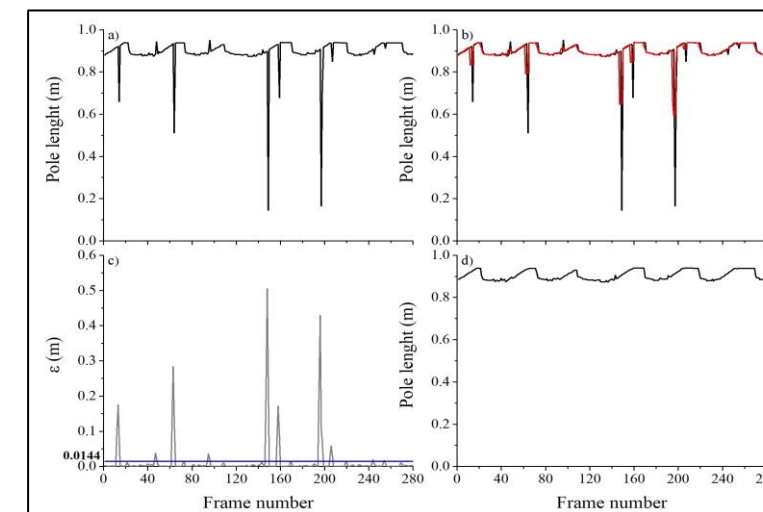
Image processing scheme: a region of interest is established in grayscale pictures (pre-processing), segmentation through Otsu's method (Otsu, 1979) is executed, images are quantized in classes, image binarization is performed (processing), and a red dashed bounding box encloses the pole (pole-identification)



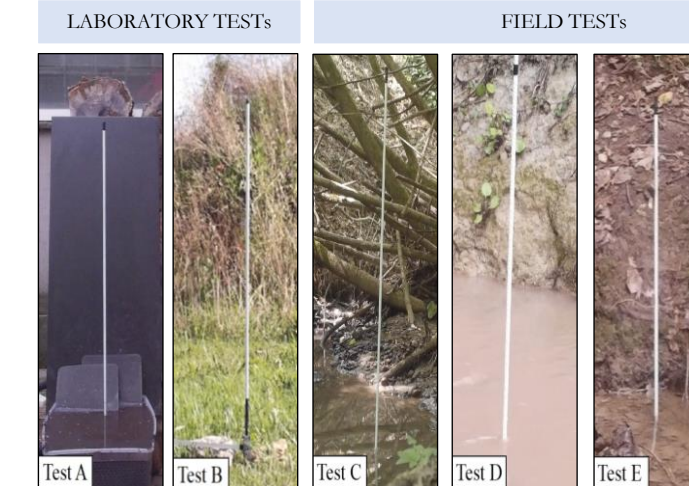
Otsu, N.: A threshold selection method from gray-level histograms, IEEE Transactions on Systems, Man, and Cybernetics, 9, 62–66, <https://doi.org/10.1109/TSMC.1979.4310076>, 1979.

DATA FILTERING

Image filtering scheme: a) time series of raw out-of-water pole length data, b) data processed through a moving average (red), c) outliers are identified as data above the 90% quantile (horizontal blue line), and d) output filtered water levels



TESTS



Experimental test conditions: a) controlled light and image background conditions (test A), b) natural illumination and background (test B), c) variable light conditions, heterogeneous backgrounds, and stream level fluctuations (test C), d) intense direct light during most of the day (test D), and e) heterogeneous backgrounds, irregular illumination, and raindrops (test E)

RESULTS

Experimental results (right): the time series of filtered water levels (blue) are compared against benchmark values for all experimental tests (red)

Test	MAE (unfilt.) cm	MAE (filt.) cm
A	0.29	0.26
B	1.07	0.57
C	1.34	0.33
D	1.39	1.54
E	2.20	2.02

Mean absolute error (MAE) values between image-based water levels and supervisedly estimated benchmark data for each experimental test. Values are computed both on unfiltered (unfilt.) and filtered (filt.) water levels

