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Outstanding Student Poster Contest

Innovative techniques and unintended use of measurement equipment

Fluorescent particle tracers for surface hydrology: development of a sensing station for field studies

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1. Abstract

This work focuses on the development and testing of a sensing station for the detection and tracking of a new class of fluorescent particle tracers for surface hydrology. This tracing methodology is based on the release of microspheres that fluoresce at labeled wavelengths in natural streams. The particles are detected as they transit below a sensing station that comprises a light source and a digital camera. Video feed from the station is then processed to obtain direct flow measurements and stream reach travel times. This novel tracing technology is a low-cost measurement system that can be implemented on a variety of real-world settings, spanning from small scale streams to few centimeters rills in natural hillslopes. In particular, the use of insoluble buoyant particles limits the tracer dispersion from adhesion to natural substrates and thus minimizes the amount of tracing material for experimental measurements. Further, particle enhanced fluorescence allows for non-intrusively detecting the tracer without deploying probes and samplers in the water.

The performance of the sensing station is assessed by conducting a large array of experiments under different flow and acquisition conditions. More specifically, experiments are performed for multiple flow velocities, camera acquisition frequencies, light sources, and distances of the sensing station from the flow surface. Particles are deployed in a custom built artificial water channel of adjustable slope to simulate varying flow conditions. A high definition bullet camera is used to detect particles that fluoresce either in green or red and two optical filters, corresponding to the emission wavelengths of the particles, are incorporated in the sensing station. In this implementation, green emission is elicited by using Ultra Violet lights, while white light drives the red emission.

Experimental results confirm the versatility and the effectiveness of the proposed methodology. Both particle types are found to be easily detected in a wide range of flow conditions. This evidence favors the use of red particles whose controlled fluorescent emission does not require costly Ultra Violet lamps and is rather based on commonly available light sources. Therefore, at a limited cost, powerful white lights can be used in the system and allow for increased fields of view.

2. Aim

In this novel technology the visibility of the fluorescent particles depends on a number of operating parameters that characterize the sensing station and its components. The "aim" of this work is to answer to the following five questions to figure out which is the tracer optimal set up.

1. Which distance (H) of sensing station from the flow surface allows to detect the tracer?
2. Which is the role of outdoor light conditions ?
3. How and in which cases the flow velocity affects the visibility of the particles?
4. The use of optical filter increases the visibility?
5. The use of the resolution WVGA improve the tracer visibility?

3. Methodology

72 visibility tests were performed by monitoring the transit of around 3 g of fluorescent particles in an artificial water channel, using:

- three different distances (H) sensory station-flow surface: 15 cm, 40 cm, 70 cm;
- two different outdoor lighting conditions (during the morning and the afternoon);
- three different flow velocities (0.5, 1, 2 m/s);
- full HD and WVGA resolution;
- with and without optical filter.

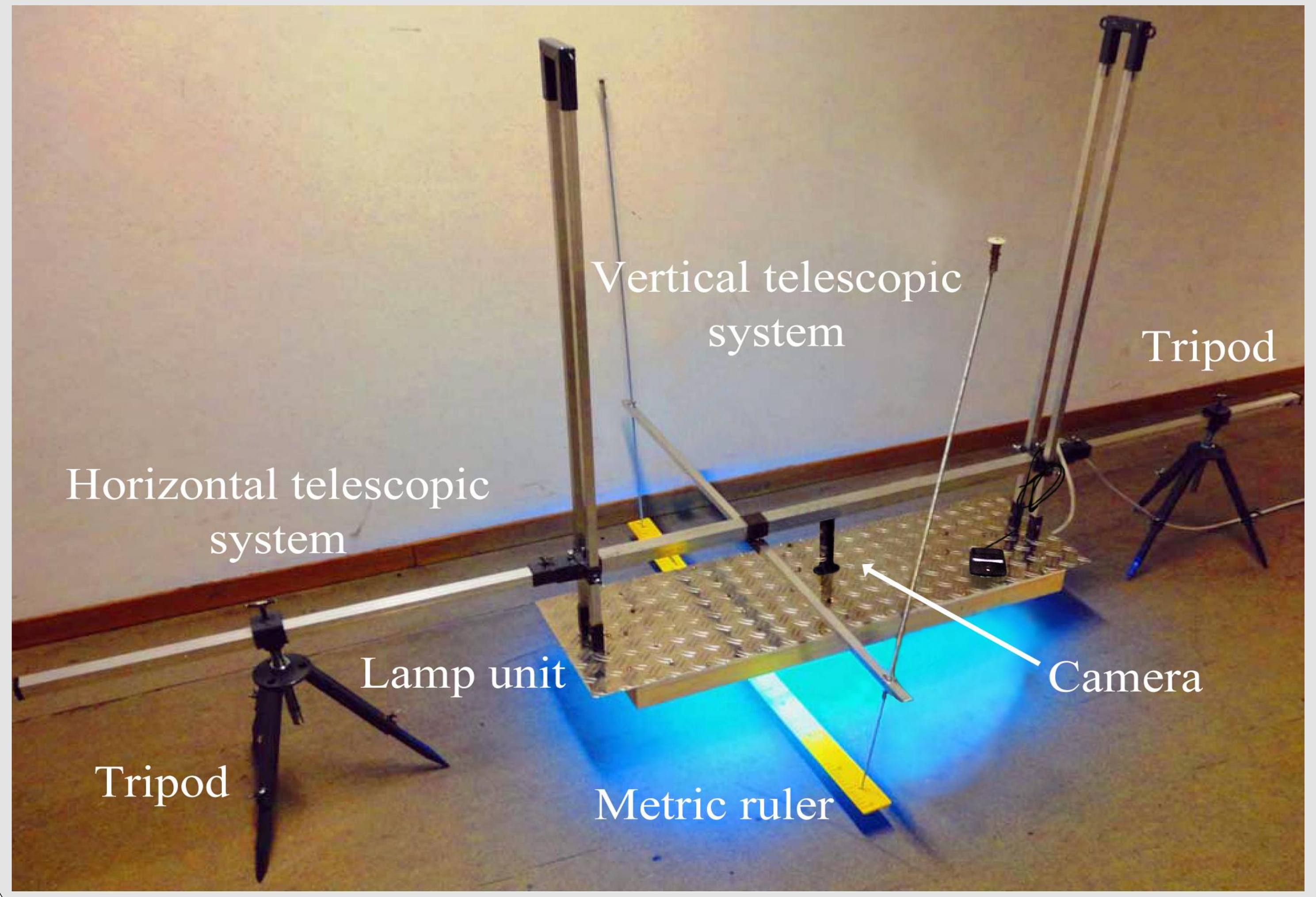
The visibility is evaluated adopting:

- A visual criterion (V): manually selecting the frames with the particle transit.
- An automatic criterion (G): applying an image-based index (G) for the entire green-channel video frame sequence.

$$G=\frac{\sum_{i\in I} c_i^{\alpha} n_i}{\sum_{i\in I} n_i}, \qquad I=\{i\in\{0,1,\dots,255\}: n_i>0\}, \qquad n_i=n_i^p-n_i^b$$

- n_i: represents the number of pixels in each class of the histogram obtained by subtraction of the background (n_i^b) from the image with the particle (n_i^p). Only the positive differences are included in the formula;
- c_i: there is the intensity class ranging from 0 to 255;
- α: exponent that increases the detectability of single or few particle transit.

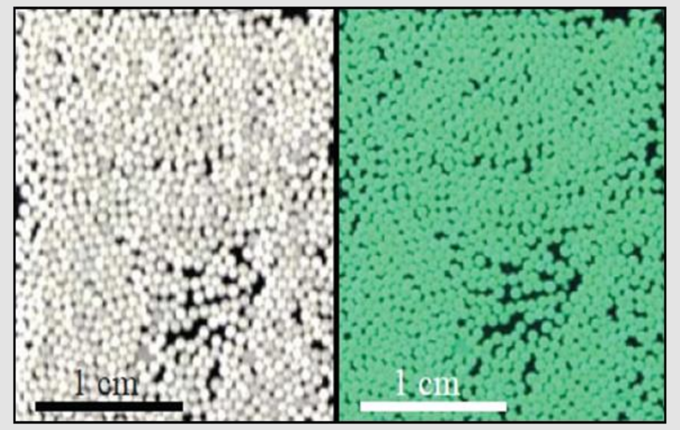
5. Sensing station



Bullet HD1080p.
Full HD 30 fps, WVGA 60 fps

Optical filter

Fluorescent particles 710-850 µm



UV lamp
8 Watt 220V-365 nm

5. Experimental results

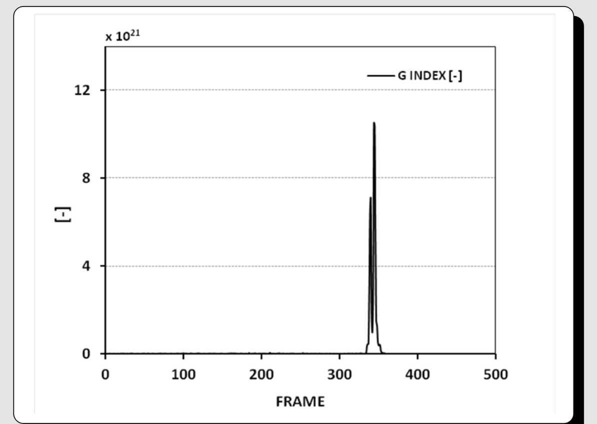
H 15 cm

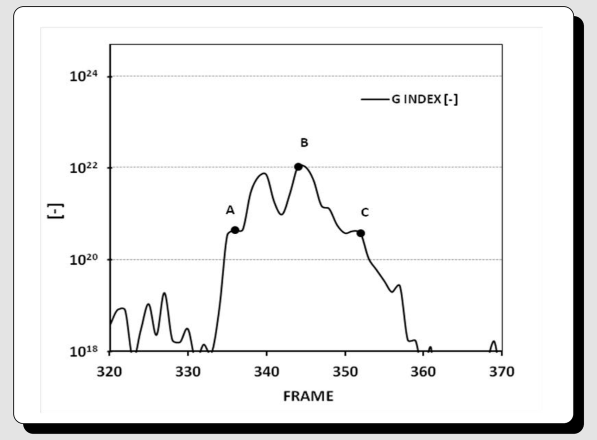
Positive (green) · Uncertain (yellow) · Negative (red)

H 15		MORNING				AFTERNOON			
		FULL HD		WVGA		FULL HD		WVGA	
		G	V	G	V	G	V	G	V
v 0.5 m/s	FILTER	YES	YES	YES	YES	YES	YES	YES	YES
	NO FILTER	YES	YES	YES	YES	YES	YES	YES	YES
v 1 m/s	FILTER	YES	YES	YES	YES	YES	YES	YES	YES
	NO FILTER	YES	YES	YES	YES	YES	YES	YES	YES
v 2 m/s	FILTER	YES	YES	YES	YES	YES	YES	YES	YES
	NO FILTER	YES	YES	YES	YES	YES	YES	YES	YES

Case study

- Fluorescent particles diameter: 710-850 µm;
- Flow velocity: 2 m/s;
- Quantity of the fluorescent particles: 3 g;
- Morning;
- Camera resolution: WVGA;
- No optical filter





A) Frame 336, $G = 4.4*10^{20}$

B) Frame 344, $G = 1*10^{22}$

C) Frame 352, $G = 3.7*10^{20}$

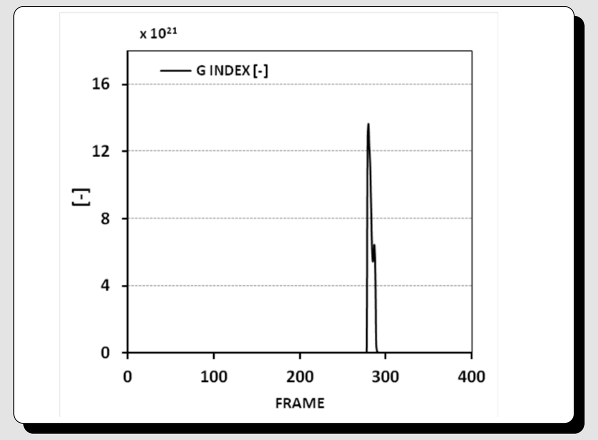
H 40 cm

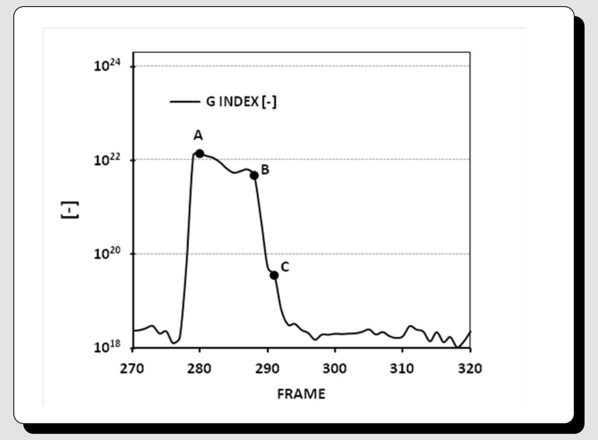
Positive (green) · Uncertain (yellow) · Negative (red)

H 40		MORNING				AFTERNOON			
		FULL HD		WVGA		FULL HD		WVGA	
		G	V	G	V	G	V	G	V
v 0.5 m/s	FILTER	YES	YES	YES	YES	YES	YES	YES	YES
	NO FILTER	SI	YES	YES	YES	YES	YES	YES	YES
v 1 m/s	FILTER		YES		YES	YES	YES	YES	YES
	NO FILTER		YES		YES	YES	YES	YES	YES
v 2 m/s	FILTER	NO	NO	NO	NO	YES	YES	YES	YES
	NO FILTER	NO	YES	NO	YES	YES	YES	YES	YES

Case study

- Fluorescent particles diameter: 710-850 µm;
- Flow velocity: 2 m/s;
- Quantity of the fluorescent particles: 3 g;
- Afternoon;
- Camera resolution: WVGA;
- No optical filter





A) Frame 280, $G = 1.4*10^{22}$

B) Frame 288, $G = 4.8*10^{21}$

C) Frame 291, $G = 3.5*10^{19}$

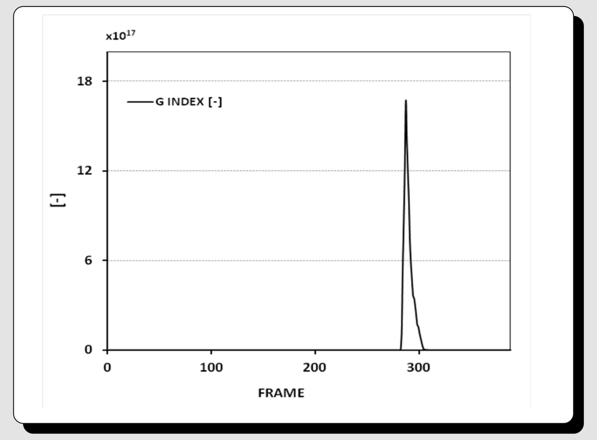
H 70 cm

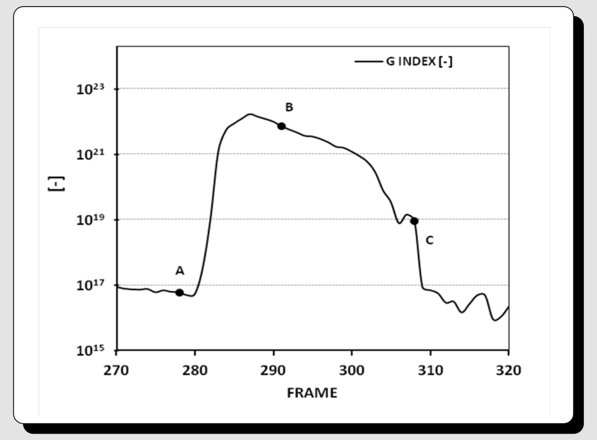
Positive (green) · Uncertain (yellow) · Negative (red)

H 70		MORNING				AFTERNOON			
		FULL HD		WVGA		FULL HD		WVGA	
		G	V	G	V	G	V	G	V
v 0.5 m/s	FILTER	YES	YES	YES	YES	YES	YES	YES	YES
	NO FILTER	YES	YES	YES	YES	YES	YES	YES	YES
v 1 m/s	FILTER	NO	NO	NO	NO	YES	YES	YES	YES
	NO FILTER		YES			YES	YES	YES	YES
v 2 m/s	FILTER	NO	NO	NO	NO	YES	YES	YES	YES
	NO FILTER	NO		NO	NO	YES	YES	YES	YES

Case study

- Fluorescent particles diameter: 710-850 µm;
- Flow velocity: 2 m/s;
- Quantity of the fluorescent particles: 3 g;
- Afternoon;
- Camera resolution: WVGA;
- No optical filter





A) Frame 278, $G = 6*10^{16}$

B) Frame 291, $G = 7.2*10^{21}$

C) Frame 307, $G = 1.4*10^{19}$

Conclusions

1. Which distance (H) of sensing station from the flow surface allows to detect the tracer? H=15cm provides the best results also varying the other parameters; H=40 seems a good compromise for having good tracer detection; H=70cm could work well in optimal light condition.
2. Which is the role of outdoor light conditions ? This is the most important parameter, only low light conditions guarentee the tracer visibility, with bright condition the particle are difficult to be detected due to the strong water reflections .
3. How and in which cases the flow velocity affects the visibility of the particles? With appropriate illumination the velocity does not affect the tracer visibility, this is due also to the high frequency of the camera.
4. The use of optical filter increases the visibility? The filter does not improve the tracer detection indeed the water reflects the light in the whole range of wavelengths.
5. The use of the resolution WVGA improve the tracer visibility? WVGA is not a limiting factor, at contrary that resolution allows to use the camera at 60Hz allowing a good particle detection also for high flow velocities.

References

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