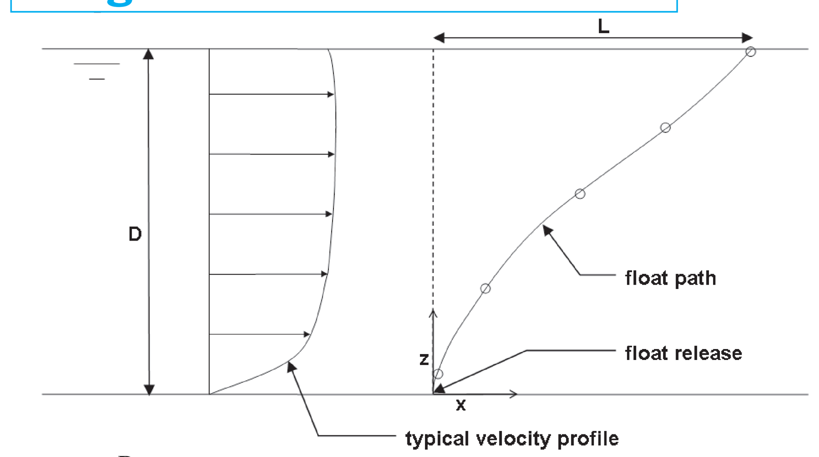
Advances in the Rising Bubble Technique for discharge measurement

Koen Hilgersom, Willem Luxemburg, Geert Willemsen, and Luuk Bussmann

Introduction

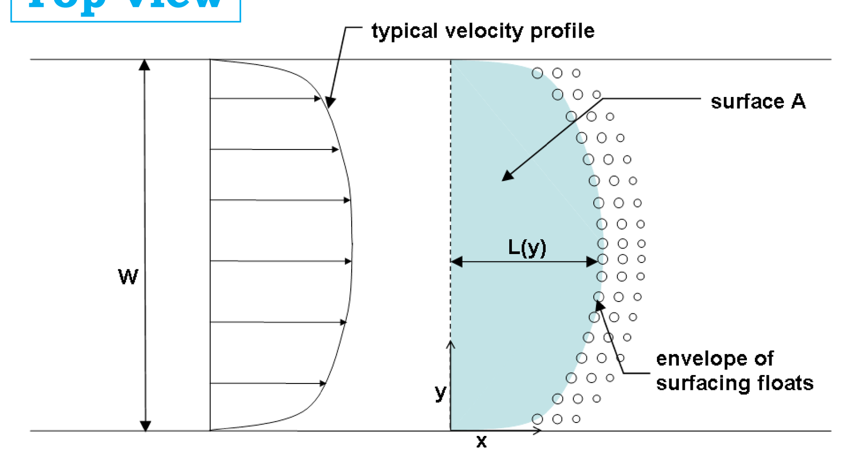
After release from the river bed, a bubble takes as much time to travel to the surface with its vertical velocity v_z as to travel forward with depth-averaged velocity v_x: $T = \frac{D}{v_z} = \frac{L}{v_x}$

Longitudinal cross-section



$q = \int_0^D v_x \mathrm{d}z = \overline{v_x} \cdot D = v_z \cdot L$

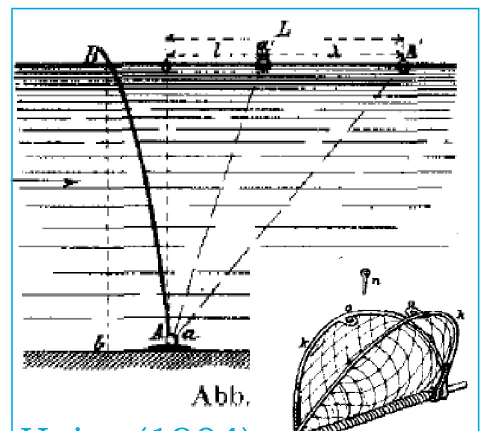
Top view



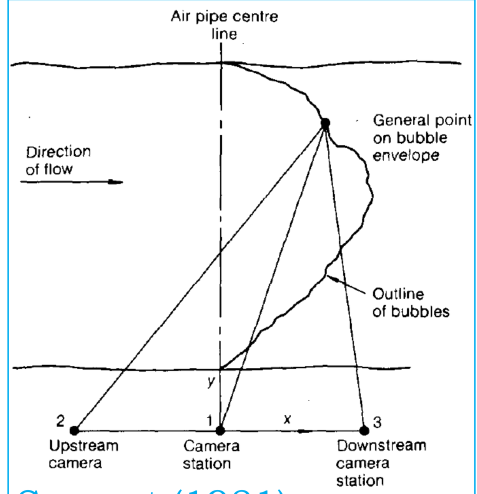
$Q = \int_0^w q \mathrm{d}y = v_z \cdot \int_0^w L(y) \mathrm{d}y = v_z \cdot A$

History:

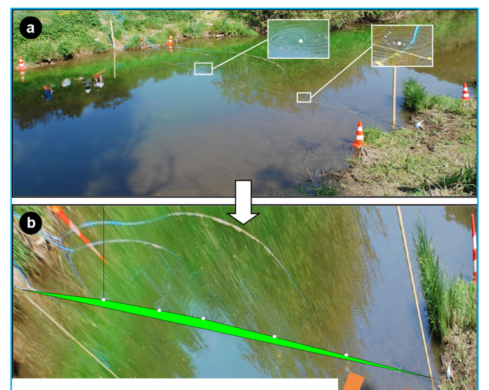
- D'Auria (1882) introduced this method measuring the distance a sinker needs to reach the river bed.
- Hajos (1904) was the first to use floats.
- Viol & Semenov (1964) applied a photo camera and introduced air bubbles as easily applicable floats.
- Liu (1968, 1970) studied the effects of, amongst others, turbulence, float accelleration, and low flow conditions on the accuracy of the method.
- Sargent (1981, 1982) made a large step forward with respect to instrumentation and applied a more sophisticated photogrammetric technique.
- Hilgersom and Luxemburg (2012) recognized the opportunities of modern photogrammetric techniques to make the Rising Bubble Technique a relatively cheap and easy-to-apply alternative in many situations. They came to interesting results:



Hajos (1904)



Sargent (1981)


Hilgersom (2012)

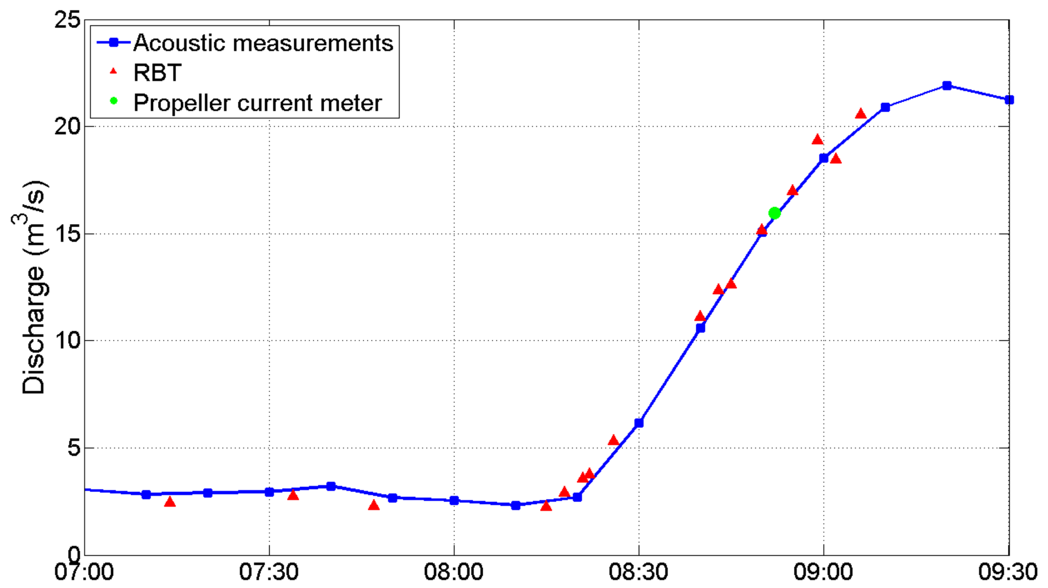
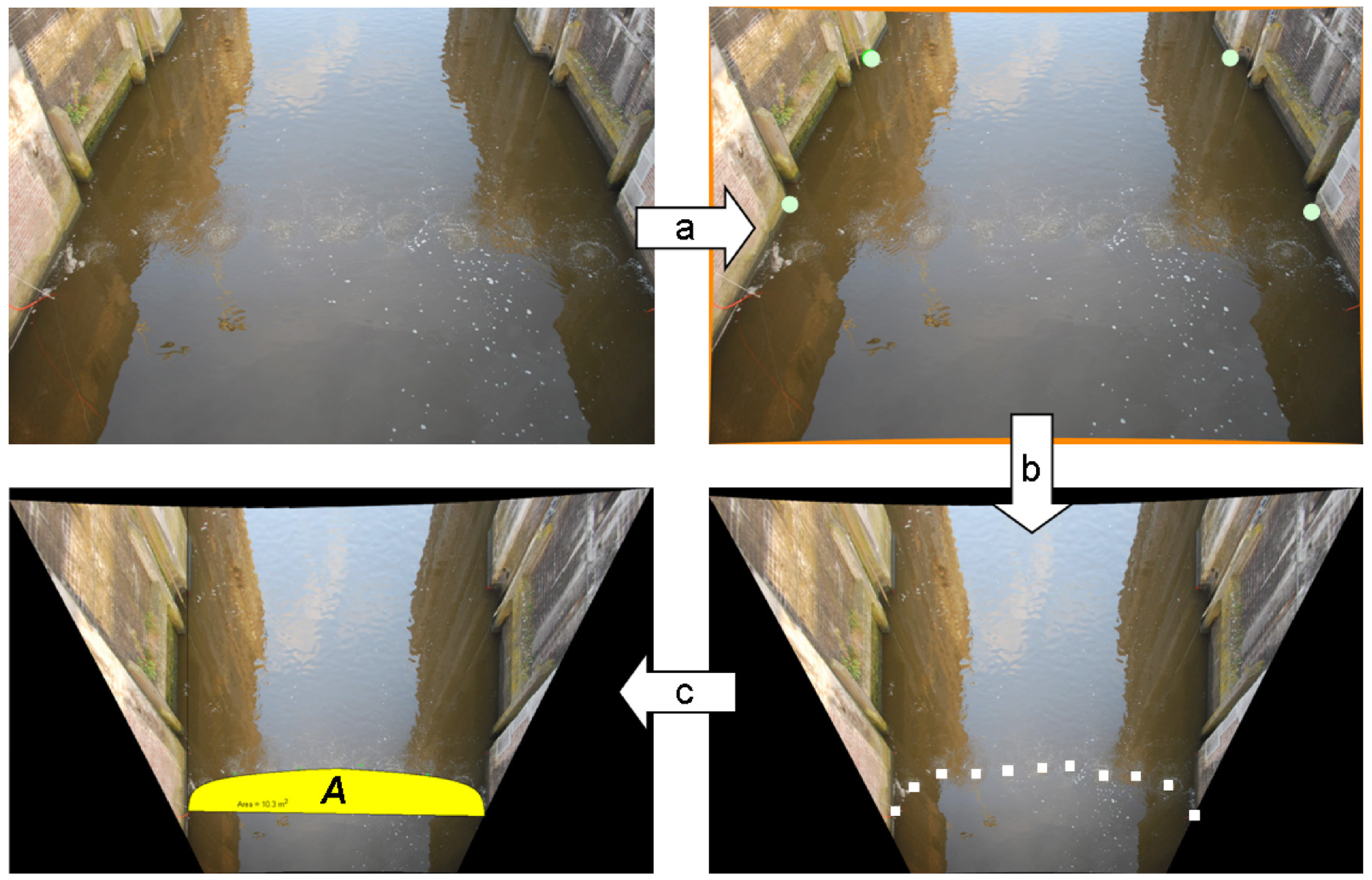


Photo	Q (l s^{-1})	Deviation
1	665	0.00 %
2	666	0.15 %
3	676	1.65 %
4	689	3.61 %
5	638	4.06 %
6	653	1.80 %
7	668	0.45 %
Average	665	1.68 %

Measurement results from an abandoned lock (left) and natural river (above)

Photogrammetry

In the 2012 paper, we showed that modern photogrammetric techniques facilitate an easy analysis of the distances in a single image by applying a simple in-house developed Matlab® routine.

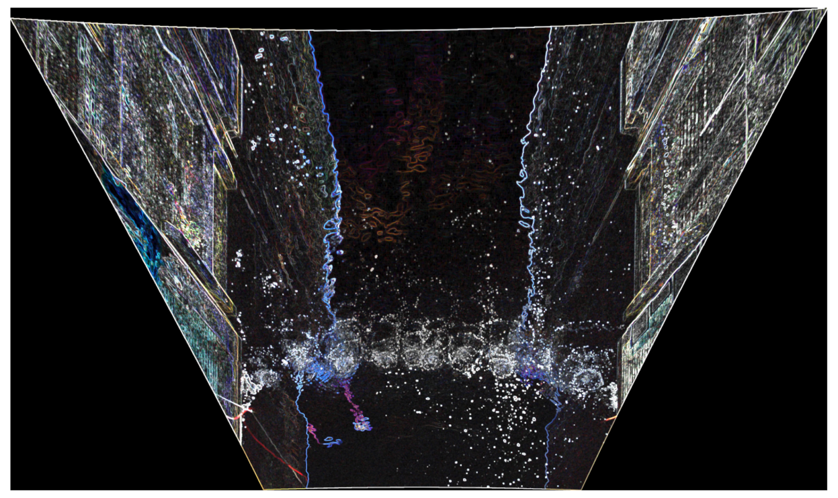


Recognizing the surfacing bubble locations:

The surfacing bubbles can be found either by the change of direction of the bubble trace when reaching the surface, or by the rings they cause when surfacing.

Automatic bubble recognition:

Automating the appointment of the air bubbles in a picture reduces the time required to analyze a picture and helps automating the entire method. First results show that this is possible, but that it is hard to create a general algorithm that works in many situations.



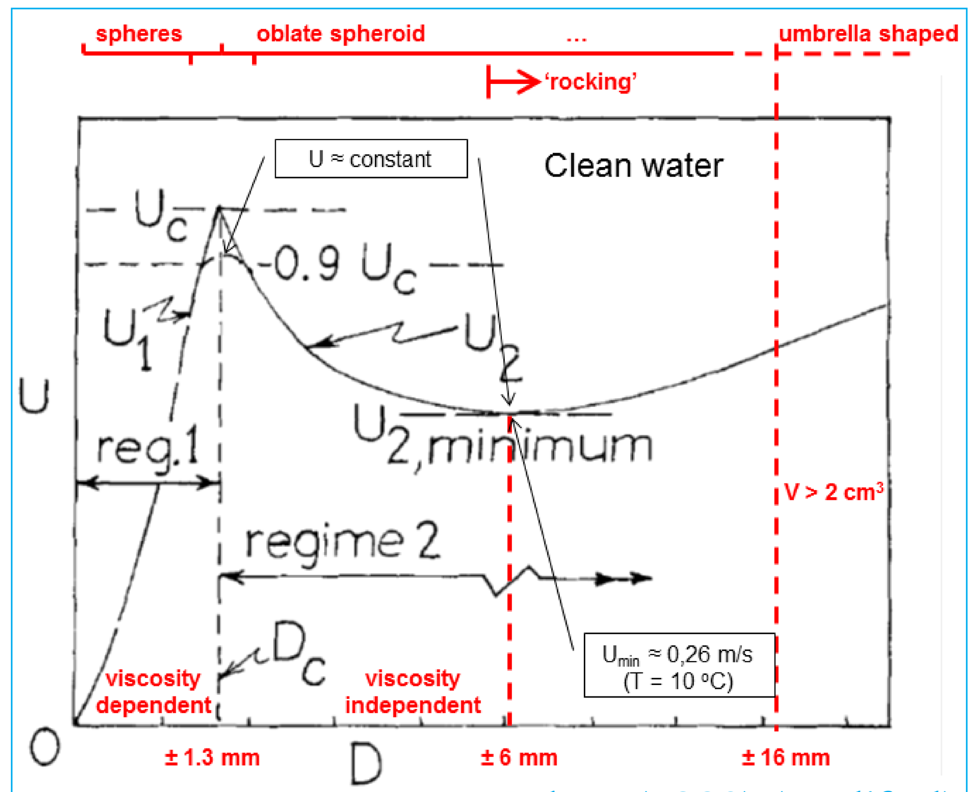
Above: the standard deviation of the pixels color value relative to its neighbours is a good filter.

Below: results from a situation specific algorithm.

Air bubble properties

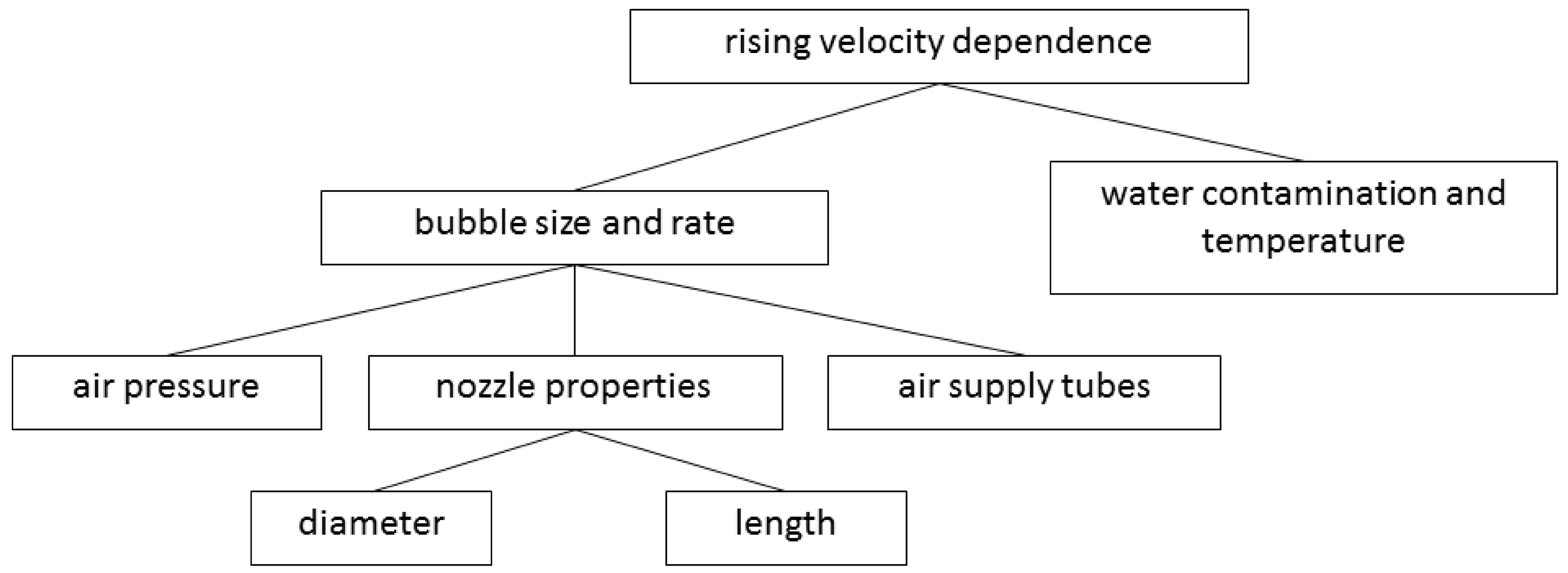
The relation between the diameter D and the rising velocity U of an air bubble has been extensively studied. The adjacent figure from Lehrer (1980) is supplemented with findings from other studies.

We aim to produce air bubbles with a fairly constant rising velocity, but that are outside the 'rocking' regime (D ≈ 3 mm).



Lehrer (1980) *(modified)*

The figure below shows a structured overview of what a bubble's rising velocity is dependent on.



After studying the effects of nozzle size and air pressure on the resulting air bubbles, we designed the nozzles displayed on the right and applied an air pressure just higher than the water pressure at the depth of the nozzle.

The dependency of the rising velocity on water contamination and temperature requires an on-site determination of the rising velocity. The best way is using an underwater camera.

Left: the rising velocity can best be determined in the river with an underwater camera.

Right: determining the rising velocity in a column is not recommended since the water temperature changes and the rising bubbles induce a circular flow in the column.

Delft University of Technology, Department of Water Management
P.O. Box 5048, 2600 GA, Delft, The Netherlands
Contact: K.P.Hilgersom@tudelft.nl
watermanagement.tudelft.nl