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Hydrology and Earth System Sciences Discussions

Interactive comment on "Technical Note: How image processing facilitates the Rising Bubble Technique for discharge measurement" *by* K. P. Hilgersom and W. M. J. Luxemburg

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First of all, we would like to thank the anonymous referee for his critical eye and the valuable comments that give us the opportunity to improve the manuscript for publication in HESS. We agree with a lot of the minor comments and we will apply the suggested improvements to the text in our final manuscript.

Apart from these, the referee has also some major concerns. We will address them point by point in this reaction. However, first of all we feel that we should clarify more on how this method should be considered according to our opinion and why we think that

the article has added scientific value, since lack of clarity in these seem to constitute the basis of the referee's major concerns.

General

We think that it is quite understandable that the Rising Bubble Technique (RBT) has never become a popular method: the time that it took to install the measurement setup in the river, to install two cameras on the banks that capture two pictures at the same time, and to process the data afterwards did not compare to the time that other methods took (e.g., propeller current meter measurements). Certainly nowadays, it is easy to use instruments like Doppler current meters to measure river discharge. Nonetheless, these modern instruments constitute one major disadvantage: they are expensive.

This fact brought us to the following idea: can we take out the major practical, time consuming disadvantages and present the RBT as a cheap and accurate alternative? Sargent (1981, 1982) already showed that this method can be accurate. Besides, photo cameras and computers are for many people readily available and cylinders of compressed air can be hired at a variety of shops and institutes. This means that they do not need to cost a lot of money, like the rest of the equipment (steel pipes and small tubes). Following from this, the major challenge for us was to improve the time consuming elements of this method.

As a start, we felt that it is possible to make the data processing stage more effective, as these data (i.e., the photographs) nowadays are directly digitally available. Since the beginning of the digital era, image processing techniques have found a large variety of applications. However, they have never found application in this field. We have shown, and this is the main novelty presented in this technical note, that digital image processing techniques can already reduce the processing time a lot. A decent computer can process an image within one and a half minute (this includes the time needed to mark the locations of surfacing bubbles, reference points and the nozzle line) and within half a minute when every photograph is taken from a fixed position (in that case, the reference points and nozzle line only need marking once, and the transformation grid to which the image is warped will also stay the same).

The time reduction that this digital process provides, was for us the reason to publish these results as a proof of concept that the RBT can be quicker than before, while being also accurate. At the same time, we argue that there are still quite some opportunities to speed up the technique, both with respect to the physical set-up and other image processing techniques.

In case multiple data points are collected (e.g., when building a time series), improvements in data processing become relatively more effective than improvements in the physical set-up. That is, the data processing needs to be performed for every single image, whereas installing and calibrating the equipment needs to be done once and becomes less significant for every data point that you add. This is another reason why we started with improving the data processing stage and think that our findings improve the method noticeably.

Concern 1

The referee is concerned with the lack of novelty that this article presents with respect to the demands to a technical note. We think that the way we look at the method is novel, taking into account the merits of digital image processing. The referee is right that the study does not include every aspect of how image processing can facilitate the RBT: results of pattern recognition techniques completely automating the method are not presented. However, we argue that the road that we took by applying digital image processing can take us there. Choosing this direction is the novelty that made us present this article as a technical note.

On the other hand, publishing this as a novel approach means that others should be

able to perform the same steps in applying the method. Hence, we agree with the referee that the technical note should include the source-code that we used to process our photographs (see Concern 2b).

The referee further argues that 'no actual image processing is applied'. In our opinion, image processing can be any type of processing of an input image towards an output, which can be either another image or data that is extracted from the image. At two stages we morph an input image towards an output image: 1) when correcting the image for barrel distortion, and 2) when warping the image projectively according to the reference points. Of course, the referee is right that pattern recognition is also a subfield of image processing, but we mentioned nowhere in the document that we applied theory from this specific subfield. Therefore, we see no reason to change the terms that we used with respect to image processing.

Concern 2a

The referee would like us to specify a niche for this method and explain how this method is able to compete in terms of time, feasibility and costs. Although we are not in favour of putting this method directly into a certain niche, we think that the method is most suitable for non-continuous measurements. During our field study, we spent no more than ten minutes installing the equipment and adjusting the air pressures. The calibration of the rising velocity, which yet is still necessary to do for the specific circumstances, took another 5 minutes. In the case of the measurements in the lock (Zoutkamp), we produced a time series over several hours for varying discharge (which one would for example do to derive a rating curve). Certainly in those cases, the preparation time becomes insignificant, and we think the RBT best suits these types of measurements.

In our article, we hypothesize that the technique may also work for continuous measurements. Although this is not the field the method was originally designed for, we can think of a situation where it is too expensive or not practical to install for example acoustic measurement devices and using the RBT becomes an option. In that case, one can install continuously working nozzles at the river bed and a camera above the water surface. Of course, there is the precondition that pattern recognition techniques appear effective to locate the air bubbles, so a computer can process the images towards automatic discharge measurements. Further research to the effectiveness of pattern recognition techniques is needed to make a stronger statement about this option. For this reason, we do *currently* not see major opportunities for the RBT as a continuous measurement technique.

The referee asked us to expand on how the method competes with other methods. There is of course a large variety of gauging methods to compare with. In the following, we select two types of gauging methods to compare the RBT with: acoustic measurements (e.g., an ADCP) and current meter measurements (e.g., a propeller or electromagnetic current meter), as they are known as methods giving sufficiently accurate results in moderate streams and canals. Comparisons are made in terms of time, costs and accuracy.

Like we explained earlier in this reply, the advantage of the RBT is that it is much cheaper than acoustic methods. However, it does not compete in terms of time. We tried to mitigate this partly with the presented approach and argue that still a lot can be done to improve in this respect, but do not expect that it can ever be a quicker method than an ultrasonic measurement. Both can be considered as relatively accurate discharge gauging techniques (of course depending on the circumstances). A choice between the two methods would be dependent on the availability of sufficient money or the acoustic device itself and the time available to perform the measurements.

If we compare the RBT with a current meter measurement, they compare in terms of initial expense. Of these, the RBT is more accurate by design (the air bubble integrates the horizontal velocity over the depth and all the verticals across the stream are measured instantaneously). Generally, the RBT is quicker than measurements with a current meter, certainly when the equipment and reference points are left on

site, or when only the air nozzles have to be re-installed. The reason for this is that a propeller or electromagnetic sensor has to be adjusted to the right relative depths in every vertical, which is very time consuming, whereas the RBT does not even require measurements of river depth.

Concern 2b

We agree with the referee that the results in an article should be reproducible. Especially a technical note should show which steps were performed in order to make the novel approach repeatable by other scientists. Therefore, the author is right in expecting that the source-code is added to the article and we will do so for a final publication in HESS. The Matlab source-code and the data (the photographs) are also added as a supplement to this reaction.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/8/C4925/2011/hessd-8-C4925-2011-supplement.zip

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