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WMO HydroHub Innovation Snapshot

Introduction to non-contact technologies for hydrometry

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This Innovation Snapshot introduces the use of non-contact technologies for hydrological measurements. An overview of general measurement principles is provided, and field applications of such technologies are presented, including some examples from the WMO HydroHub Second Innovation Call in 2020. This document is not intended to provide detailed technical guidance for National Meteorological and Hydrological Services (NMHSs), but rather a snapshot of examples of recent innovations in the field.

1. Introduction

Business as usual is no longer an option if we want to seriously engage in poverty alleviation, the Sustainable Development Agenda for Sustainable Development Goal 6 (SDG6), and robust climate change adaptation. These undertakings all require reliable, and accessible hydrological data for both the public and private sectors. To meet this need, many current hydrometric monitoring systems – especially in developing and least developed countries – need optimization of their efficiency and cost. This is highlighted in the World Bank Report "Assessment of the State of Hydrological Services in Developing Countries", which indicates that only 9% of developing countries that participated in the assessment have adequate water monitoring networks.

Currently, emerging innovative technologies and approaches, including non-contact technologies offer new opportunities to complement and enhance in-situ measurements and contribute to closing the hydrological data gap. Their operational uptake by National Meteorological and Hydrological Services (NMHSs) is however currently low due to insufficient collaboration between innovators, hydrometric services, and their user communities, insufficient translation of research into operational tools, and/or high costs of technologies and their ownership/operational costs.

To address this, the WMO HydroHub organizes Innovation Calls that aim at finding and operationalizing innovative technologies and approaches addressing the hydrometric challenges of NMHSs.

This Innovation Snapshot explores emerging non-contact technologies for hydrometry, including some developed in the framework of the WMO HydroHub Second Innovation Call.

2. Advantages

Non-contact technologies present many advantages when compared with traditional contact measurements, including:

- Non-contact technologies can be used without being placed in water, which can often be challenging due to in-channel hazards.
- Non-contact technologies are often safer for staff when it comes to their maintenance.
- Non-contact technologies cannot be damaged by debris or harsh flood conditions which in turn improve the reliability of data streams in installations for flood early warning systems.
- Non-contact technologies can reduce fieldwork costs/time due to both fewer loggers being lost and easier access for maintenance and could potentially be affordable/cost-effective for low-income countries.
- Non-contact technologies might reduce the risk of human-made errors, thus improving the accuracy of the data collected.

3. General Principles

Non-contact methods presented here can be used for measuring the water level, the surface velocity of a water body, and combining that information to get the discharge.

In the first case, they make use of the travel time of a wave (acoustic or electromagnetic) emitted by the instrument to reach it after being reflected by the water surface, with the return time proportional to the distance.

In the second case, instruments measure the Doppler effect on the wave beam reflected by the surface, or the movement of surface features (natural, as ripples and waves, or artificial as floaters) captured in a sequence of images (usually in the visible range). Measures can be affected by surface reflectiveness and roughness, air temperature (affecting sound speed and deforming the geometry of the installation), wind gusts (that may affect the speed of water surface), and errors in the orthorectification of images, but in general such methods are relatively easy to install and use by skilled and adequately trained technicians and provide reliable results.

4. Examples of methods

4.1. Lidar-based non-contact hydrometry for mountainous terrain

The Riverlabs UK lidar-based water level sensor leverages open-source technologies to provide a bespoke solution for measuring water levels (Paul et al., 2020). A key element of this technology is its flexibility. Some of its components can be easily upgraded, and the solution can easily be adapted to different use cases. The lidar-based technology proposed in the project was extensively tested by Imperial College London to understand and optimize its performance under various environmental conditions such as distance, turbidity, inclination, temperature, and water surface roughness. The technology leverages the advantages of open hardware (and open science, more generally) by using existing hardware designs and software code available in the open hardware community to build a non-contact solution of comparable data quality (accuracy and sensitivity) at a much lower cost compared to other market-available non-contact technologies. In addition, the proposed sensor has some advantages, especially its unique ability to make accurate measurements under an angle of inclination up to 30°. This makes it particularly suited for application in remote regions, for rivers with unstable riverbeds and little to no infrastructure (where installing non-contact sensors above the water surface is challenging, as is required for methods such as radar and ultrasound).

4.1.1. Principle

A lidar-based water level sensor is a non-contact sensor based on the measurement of the time-of-flight of a near-infrared pulse to estimate the distance to the water surface from the sensor. This technology is similar to ultrasound and radar water level sensors. However, ultrasound or acoustic sensors have a limited range (typically only 5 m) and are known to be sensitive to temperature, which is not the case for radar and lidar. And radar (10^9 Hz) has a wide beam and must be installed directly above the water surface to capture diffuse reflections.

Lidar (10^{12} Hz) has a narrow beam, measures over a minimal footprint, and can send a sufficient signal back to the sensor even when observed at an oblique angle.

Lidar ranging depends on the rugosity (roughness) of the measurement surface to generate a non-specular reflection of the laser pulse (Figure 1), resulting in incipient laser beam scattering.
Commercially available laser emitters are pulsed laser diodes available in wavelengths 905 nm and 1550 nm. Though 1550 nm lidar rangefinders were earlier promoted for rangefinding applications since they are safe on the eye, they are not helpful for interaction with water surfaces since the entire signal can get absorbed in the water media without reflection. The 905 nm occupies a "sweet spot" on the spectral reflectance signature of water (Figure 2) with a small % reflected and most of the signal either transmitted or absorbed. Since laser beams have high energy and a slight beam divergence angle, a small reflection is sufficient to return a signal to the sensor. The water attenuates reflectance from the riverbed, so the signal received at the sensor can only originate from the water surface (Figure 3).

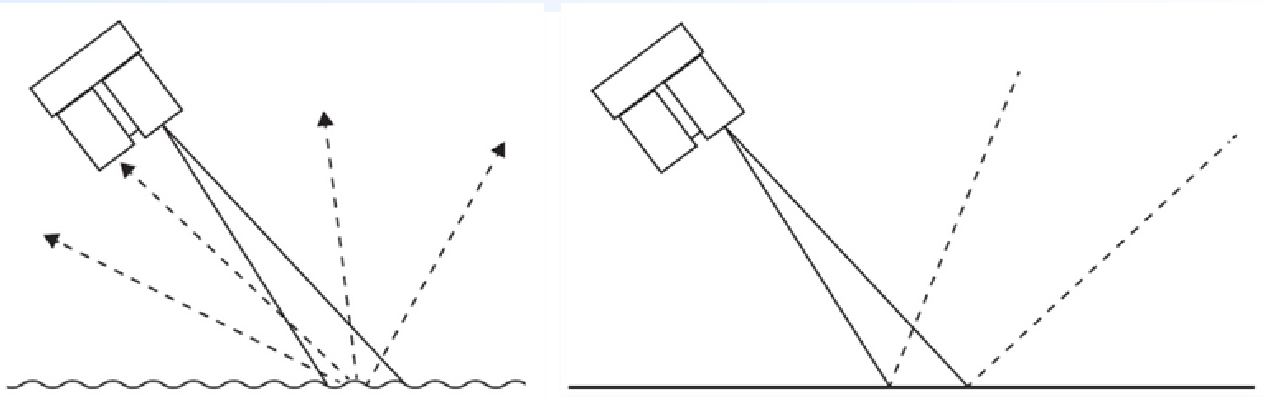

Figure 1. (left) Diffuse reflective surface; (right) Specular reflective surface (Source: Garmin Lidar Lite v3 manual)

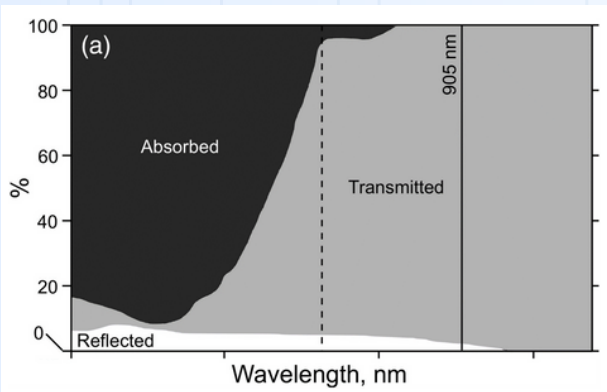

Figure 2. Spectral properties of clear water as a function of laser wavelength (Paul et al. 2020, Lednev et al. 2013; Milan et al., 2010)

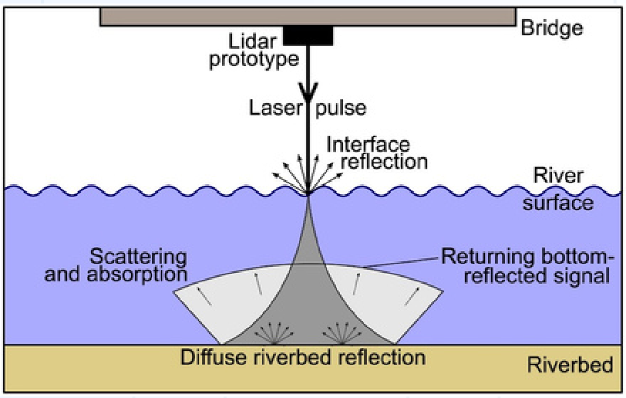

Figure 3. Schematic of lidar water level sensor illustrating the fate of laser pulses (Paul et al. 2020)

4.1.2. Technical Design

A low-cost implementation of a lidar water level sensor was developed for the WMO HydroHub Second Innovation Call. The main components consisted of:

- Microcontroller – Atmel Atmega 328p (8 bit, 8Mhz)
- Sensor – Garmin Lidar Lite v3HP
- 18650 Li-ion 3.7V battery; 2W solar panel
- EEPROM internal storage and S.D. card slot
- RTC (real-time clock)
- Arduino bootloader and 6-pin FTDI serial interface
- DIGI XBee cellular 3G/4G modem

The water level sensor uses the Arduino bootloader, which allows using the many Arduino-compatible software libraries available in the open hardware community and the Arduino IDE, which is both user-friendly and convenient. It can be programmed to make observations at a user-defined "READ INTERVAL" specified in minutes. At a READ event, the sensor takes nine observations and stores the median of the observations. The user can specify the number of readings (NREADINGS). Higher NREADINGS may be set if the environmental conditions do not allow sufficient signals to return to the sensor.
Telemetry is implemented using a DIGI XBee 3G/4G cellular modem using the COAP protocol. Data is transmitted to a Thingsboard server for data download and visualization. In keeping with the open hardware philosophy, the latest source code for the implemented solution is available on the GitHub platform.

4.1.3. Advantages and limitations

Paul et al. (2020) tested the performance of the lidar water level sensor under a range of environmental conditions. Presented here are two measures of performance – precision and oblique angle observational accuracy. The relative error for measured distances up to 35 m was less than 0.1% though absolute measurement bias increased with distance. The results were within the Garmin specifications for measurement precision. For oblique angle measurements, bias and variance increased with incidence angle due to beam divergence. However, the bias was limited to a few cm for inclination angles up to 40°. The performance of the lidar sensor in oblique angle installations can be considered acceptable in many operational conditions, hence the potential for the lidar water level sensor to take observations from river banks. Other strengths and limitations of the lidar water level sensor are tabulated below.

Table 1. Summary of strengths and limitations of the lidar water level sensor

Strengths	Limitations
Low cost	Accuracy in centimeters
Low power consumption	Stage measurement, not discharge
Higher frequency signals	New technology, less tested compared to other mature technologies
Tight beam	Not suitable for clear water
Non-contact	
Deployable at angles up to 30°	
Long-range (up to 40 m)	

The lidar water level sensor was introduced to the Central Water Commission (CWC) in India through the WMO HydroHub Innovation Call. Technologically, the lidar water level sensor leverages the challenges faced by CWC to hydrometry in mountainous terrain to its advantage. Steep river banks favored oblique angle installation, and the low cost of the open-source solution boded well for the expansion of river stage monitoring in rugged terrain within the existing budgetary allocation of the NMHS. Representative river stage observations recorded during a 31-day period in August 2021 at Haridwar on the River Ganga show close agreement between CWC water level records, and measurements made using a river bank installation of the lidar water level sensor (Figure 4).

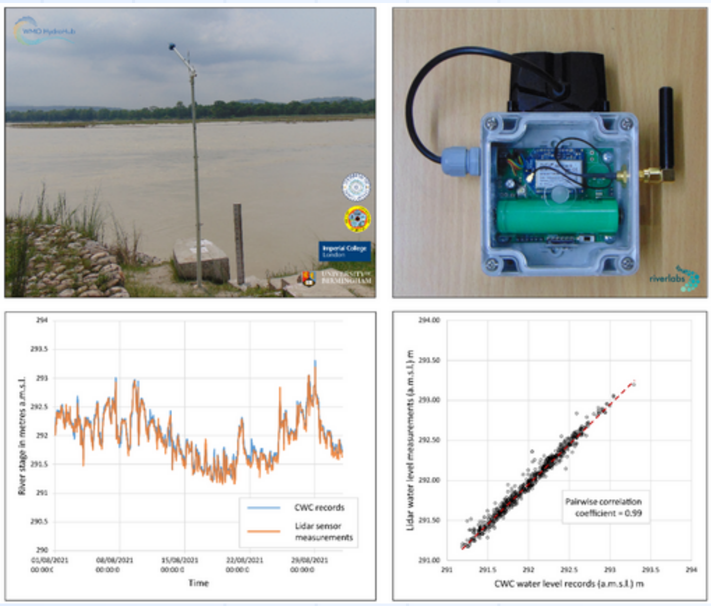

Figure 4. (Anticlockwise from top-left) River bank installation of lidar water level sensor at Haridwar on the River Ganga, India; Time series of river stage observations at Haridwar on the River Ganga; Pair-wise scatter plot between Central Water Commission (CWC) gauge records and lidar water level sensor readings; the low-cost lidar water level sensor developed for the WMO HydroHub Second Innovation Call.

4.1.4. Challenges to the widespread buy-in of low-cost sensors

Many technical bottlenecks to low-cost sensor networks have been addressed during the last decade of practice. However, the potential benefits of low-cost sensors are not fully realized in real-world applications. Mao et al. (2019) test some hypotheses about research in low-cost sensor networks. They identify a bias towards data collection activities with lesser emphasis on other downstream activities in scientific literature. Further, low-cost solutions presented in the scientific literature are primarily designed for technically orientated single end-users. Consequently, they are more likely to be adopted by students and researchers and less likely to find acceptance among field hydrologists in government departments with diverse end-user preferences.

Likewise, notwithstanding the advantages of the lidar water level sensor to the CWC, there remains a reluctance among the engineers to the buy-in of the new technology. Programming the sensor microcontroller through the Arduino IDE represents a barrier to engineers unfamiliar with electronic circuits and programming. Instead, the NMHSs would require user-friendly factory-programmed systems with minimum field customization, cost notwithstanding. But this reluctance is not a fundamental limitation of the proposed open hardware solution but only indicates that the market for businesses based on open hardware is still nascent. Governments already use a considerable amount of open-source software because there is a mature market for commercial services based on open-source software products (e.g., companies such as Red Hat, now part of IBM). A similar business model is also viable for open hardware technologies; it just does not exist yet.

4.2. Open-source non-contact river flow observations with cameras

During the WMO HydroHub grant titled “Open-source non-contact river flow observations with cameras for Africa”, an open-source workflow was developed for, as the title suggests, river flow measurements with cameras. This chapter contains texts from the website that was produced during this project, and which is continuously updated. In a nutshell, OpenRiverCam is a fully web-based solution for setting up and maintaining river observation sites for river flow monitoring with cameras. The software’s backend is based on Large-Scale Particle Image Velocimetry (LSPIV), and geographical ortho-projection methods. With affordable camera equipment and a single field survey, one can start monitoring river flows. The software can be deployed locally or in the cloud. Its user-friendly web interface can be accessed via smartphone, tablet, laptop, and desktop, all in a simple browser.

The challenge solved here is that the complex workflow has been automated and that users anywhere can perform the analysis, also without access to high-performance computing equipment. Also, there are no costs associated with the use of software as all steps are covered by open-source software. The work presented here has mainly been undertaken by Hessel Winsemius of Rainbow Sensing and Rick Hagenaars of the Trans-African Hydro-Meteorological Observatory (TAHMO).

4.2.1. Measurement principles

The standard way to measure river flow is to install a gauge that is read regularly, either by hand or automatically. These height measurements are combined.

The software's processing capabilities heavily rely on a scientific computer vision approach to estimate movements from videos called "Particle Image Velocimetry". In the snapshot below, one can see the results. A movie shot of a few seconds is projected onto a geographical plane. Displacements of patterns are estimated from frame to frame. Patterns that can be traced are, for instance, debris floating by, or eddies in the water. Spurious displacements or displacements that are not part of the stream are filtered out using automated filtering methods. The resulting velocities can then be displayed on top of the movie frame. This shot was taken at the Chuo Kikuu stream, in Dar es Salaam, ia. Using a measured cross section and the water level during the video, the velocities can be integrated into a river flow. Presently, integration takes place by assuming the generally valid logarithmic velocity profile, with zero speed at the bottom and the measured speed at the top. A more complete hydraulic model allowing for 3D flow would be a future improvement.

Figure 5. Surface velocity estimates at Chuo Kikuu, Dar es Salaam, Tanzania

By simultaneously measuring the water level, it becomes possible to collect over time a stage-discharge rating curve. One can either measure the water level independently or, more conveniently, with the same camera. Once the rating curve is established, simple level measurements will suffice in most cases, until major changes in streambed geometry occur.

4.2.2. Practical Sensors

In OpenRiverCam, for each site that needs to be monitored, a camera needs to be installed. This camera is of a specific type and will be installed at a certain position, looking at the stream at a certain angle. Furthermore, the camera will record videos with a certain resolution and frame rate. This may differ per site.

In order for OpenRiverCam to be able to extract frames from a video, understand how to ortho-project them on a geographical surface, and understand at what spatial scale it should look for traceable patterns on the water surface, a camera configuration is needed.

The configuration parameters needed are:

- k1: barrel lens distortion parameter. This parameter describes the curvature of the lens. The fact that a lens is curved makes the center of a photo or video magnified slightly more than the edges. That makes straight lines appear to curve around the edge of the image. The exact value is typically a very small negative number for lenses that are thicker in the middle, and positive for lenses that are thinner in the middle than at the edge. For instance, a typical value could be -0.000005. If this factor is not known, a default value of 0 is recommended.

- c: optical center. This parameter determines which point on the lens is the point where light passes through on a straight line. The most common value is 2 (meaning that the light passes straight at the center of the lens), which is also the default value.

- f: focal length of the lens, measured in millimeters (mm). Usually, this parameter can be found on the lens manual. Typical values for security cameras are in the order of 4 mm, which is commensurate with a very high view angle. A default value of 10 mm is recommended when this information is not available.

The effect of the corrections can be seen in the images below.

Figure 6. Uncorrected (L) and corrected (R) picture.

4.2.3. Installation

The camera should be installed at a safe site with a good view of the complete stream. Special care needs to be taken to avoid filming people as much as possible for privacy reasons. If the camera can be installed safely on a bridge, this would be a good option especially because the stream section around bridges tends to be relatively fixed. Especially when real-time video streaming is needed, the set-up will require either power from a reliable power outlet, or a large (100W) solar panel and proper batteries.

During the installation, four control points need to be identified and measured, either with a theodolite or a GNSS (GPS) receiver. In OpenRiverCam, affordable high-accuracy GNSS receivers that are accurate within a few millimeters are typically used. These four points should be within the field of view of the camera. In order to translate a simple movie of a few seconds into stream velocities and river discharge, it is necessary to translate the locations of individual pixels in movie frames, into geographical coordinates. In other words, a certain row and column in a photo need to be transformed into a northing and easting coordinate. And once velocities are known, one needs to know how deep the water is over a minimal cross-section in order to estimate river flow.

The process of making a photograph geographically georeferenced (i.e. as if one is looking at the scene from above and pixel distances are measured in meters) is called ortho-projection. It is demonstrated in the figure below with a single frame from a 1080p movie from the Chuo Kikuu stream, at Uhuru Labs. In this case, a camera was mounted on an approximately 3-meter-high perimeter wall, with electricity and internet available within the perimeter. The left-hand side shows the original photo, with clearly marked ground control points, represented by 4 sticks placed in the water with good spread in both upstream-downstream directions and left to right bank direction. The right-hand side shows the same but now projected onto a horizontal plane.

Figure 7. Installation at Chuo Kikuu, Dar es Salaam, Tanzania

Detailed instructions on site surveying can be found here.

4.2.4. Data acquisition and processing

After setting up a site including a staff gauge, configuring the camera, and providing cross sections, individual short movies can be processed into surface flow velocities and river discharge. Movies of 5 seconds at 1080p resolution and 25 or 30 frames per second at a 5Mbps bit rate are enough to yield good results. The process that OpenRiverCam follows for this is displayed in the schematic below. The process can be run fully automated.

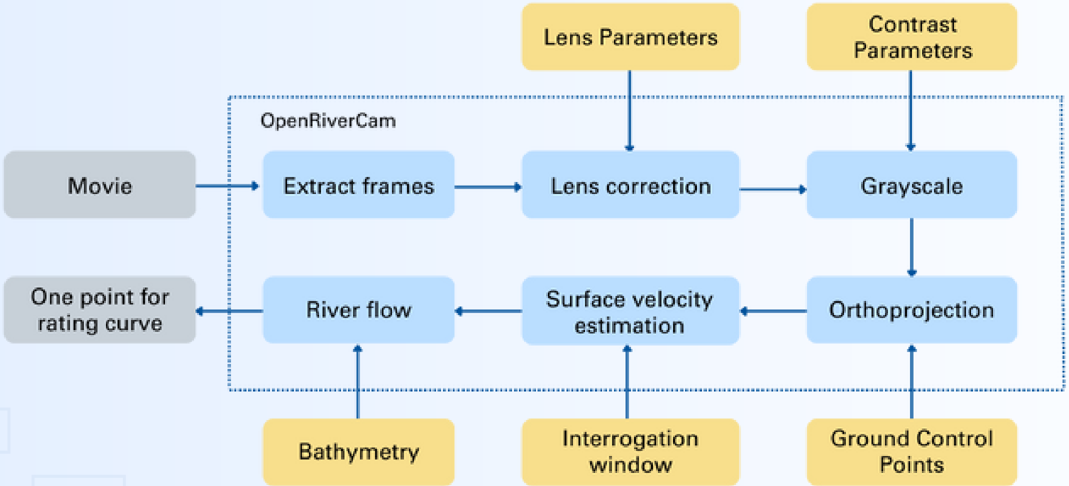

Figure 8. OpenRiverCam process

The main innovation of OpenRiverCam is the automated workflow that can either take place locally or through contact with the organization, on servers run by OpenRiverCam. Once installed or accessed, the user is taken through the different steps in an easy-to-use browser (Chrome) interface.

First, the site itself needs to be registered and located geographically. Next, the camera used needs to be entered with the camera parameters, as described above. The next step is to enter the bathymetry as a simple comma-delimited text file that contains depth and geographic coordinates. There are functions to change between different coordinate systems.

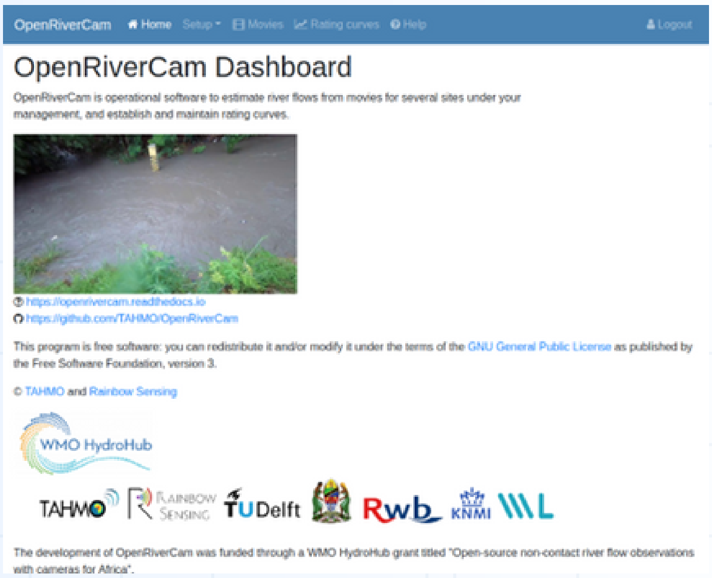

Figure 9. Screenshot OpenRiverCam Dashboard

Next, the four control points for the camera need to be entered, together with the exact x,y, and z coordinates of the camera itself. Finally, movie clips can be uploaded for analysis. The results from all movie uploads are collated to produce a rating curve with uncertainty estimates. The whole process can also be automated, resulting in ever-improving rating curves.

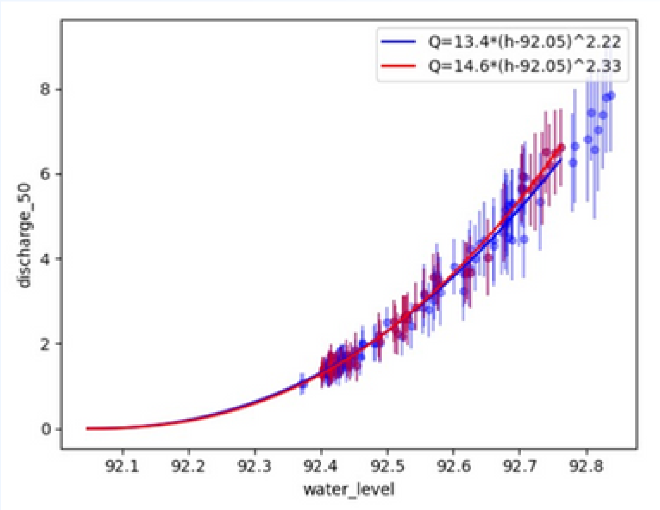

Figure 10. Rating curve after one month of measurements

4.2.5. Advantages and limitations

The advantages of this technology are that its costs are very low and that information on the rating curve is updated continuously. The latter part is especially important when it comes to peak flows. The costs of maintaining a gauging site consist mainly of the establishment of a good rating curve. During high flows, traditional flow measurements with flow meters are very difficult. In addition, one must be in the field when it happens, which is usually not the case. This is why, especially in resource-poor environments, this method is recommended.

Although not yet part of the present setup, it is planned to include more extensive hydraulic modeling. It will then become possible to produce error estimates. When these estimates become too high, there has probably been a change in the geometry of the streambed, forcing new measurements. Other methods do not have such an "alarm."

The process is, for the moment, somewhat limited to small streams and rivers. For the use over wide rivers (>100 m), it becomes more difficult to obtain sufficiently high-resolution coverage over the complete width. When a bridge is available, this could be overcome by placing multiple cameras, but this has not been done yet.

A second point that needs further development for larger rivers is determining the bathymetry plus the topography of the adjacent floodplains. Work is underway to use simple fish finders combined with low-cost high accuracy GPS measurements for bathymetry. The topography can be surveyed with affordable UAVs. The integration of bathymetry and topography into a seamless geometry is ongoing work.

Finally, the video clips are relatively large, making near-real-time streaming difficult, especially where mobile network coverage is spotty. On-site analysis of the videos through edge computing, would make this method more robust, especially because it would then be possible to communicate through satellite uplinks. For now, an alternative is to store the videos locally on SD-cards, which can be collected periodically, while communicating just water levels.

4.3. Smartphone-based methods

Institutions in charge of managing water resources are often hampered by the lack of data and resources to acquire flow data, especially in emerging economies. Some of the reasons for the lack of data are the high investment costs, as well as the operational and maintenance costs of traditional hydrometric methods. Hence there is a need for cost-effective and easy-to-use monitoring devices.

In the last years, smartphones have become powerful and include several sensors like accelerometers, gyroscopes, cameras, etc. Even more, by making use of internet connection, data can be readily available. These capabilities make them suitable for other applications like water monitoring. Additionally, smartphones' availability in all regions of the world is continuously increasing, making them a great tool for being used as measurement devices. Their simplicity of usage makes them ideal to be used not only by experts but also by untrained citizens.

Using smartphones and available applications, measurements can be made at a much lower cost, since there is no need for permanent installations.
An example of such applications is the DischargeApp (DApp) which allows to measure discharge in small to medium-sized rivers and channels using the smartphone's camera and its computational power. In this case, all the calculations are done in the smartphone. Once the measurement is done, if there is an Internet connection in the field, it can be sent to a cloud-based database, where it can be managed, analyzed, and shared or exported by interested stakeholders.

The usage of the DischargeApp is very easy, which opens the possibility to involve non-specialized persons in water flow monitoring.

4.3.1. Measurement principles

Before making any measurement, at the point of interest 4 Ground Control Points (GCP) have to be installed and their coordinates as the cross-section have to be introduced into the DApp.
The DApp calculates the discharge by applying the area velocity method: by knowing the cross-section, the water level, and the depth-averaged velocity, the discharge can be computed. The DApp records 5 seconds of a video which is used to measure the water velocity at the surface and with the information on the river roughness the surface velocity is converted to depth-averaged velocity. The water level is calculated by the DApp by selecting in the image the intersection between the water level and the shore (Figure 11B).

The DischargeApp's Graphical User Interface guides the user through the main steps to introduce the needed data on to execute the calculations (Figure 11). One can have many monitoring sites in the DApp, the first step is to select the site (Figure 11A) then a 5-second long video is recorded. Afterward, the user must identify the GCPs position on a frame of the video (Figure 1B). At this stage, the camera calibration (compute the camera extrinsic parameters) is done, which is used to transform between image coordinates and world coordinates (all these calculations are done in the background). The next step is to give the water level, this is done by manually identifying the shoreline and as the camera is already calibrated in the previous step and with the knowledge of the cross-section, the DApp can calculate the river stage (Figure 11C). In the last step, the DApp computes and displays the surface velocity and the discharge (Figure 11D). Finally, the user, if desired, can upload the results to the cloud.

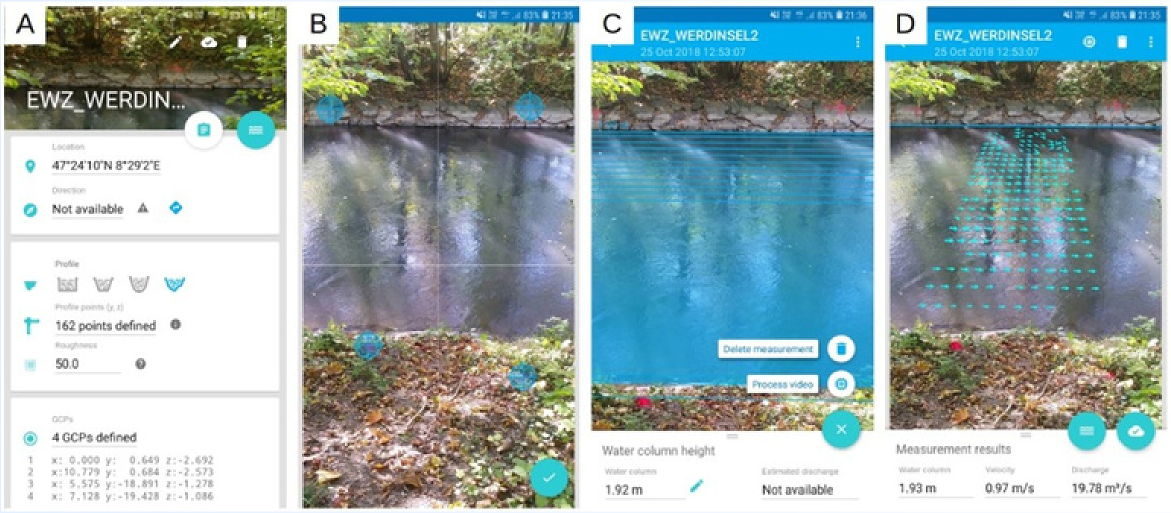

Figure 11. Steps for taking a measurement with the DApp

For a typical setup, the time required for the whole procedure is of around one minute per measurement.

4.3.2. Installation

One of the advantages of the DischargeApp is that no hardware is installed at the site, making it cheaper, maintenance is almost none and it is vandalism free. However, it is necessary to have four GCP placed at the monitoring site, 2 at each bank of the river (Figure 11B). The GCP can be anything, from some painted marks to more permanent markers, the distance between the GCPs has to be measured and introduced into the DApp (Figure 12). For a canal with a regular shape, setting up a site takes around 15 minutes and it has to be done only once.

Cross sections that do not have a regular shape can also be set up, the only difference is that the values cannot be entered directly from the DApp, they have to be entered using the web application. The site settings are fully synchronized between the DApp and the web application.

Figure 12. Site setup for the DischargeApp

In rivers or canals where there is sedimentation or where the cross section can undergo changes, it has to be remeasured again after any major change, since having a wrong cross-section will affect the accuracy of the calculated discharge.

Using smartphones for discharge measurements opens many possibilities in hydrometric monitoring to collect information where it is scarce. Additionally, involving citizens in data collection has indirect advantages as the population is becoming more aware of the problems and solutions. However, this approach to collecting data is prone to errors and higher uncertainty.

Peña-Haro et al, 2022 collected discharge data on a 50 m wide river using the DischargeApp (31 measurements that 16 citizens took using 5 different smartphones during the 3 hours). The average discharge measured with the DApp was 37.88 m^3/s, the ADCP measurement was 43.06 m^3/s while the official discharge was reported at 40.0 m^3/s. Hence the relative error compared with the ADCP was 12% and compared to the official value it was 5%. The DApp calculates the uncertainty of each measurement by considering different types of sources: survey (GCP, bathymetry), water level, surface velocity, and in the calculation of the bulk velocity. For a particular measurement the discharge was 42.82+/-1.22 m^3/s. The uncertainty of the measurements due to different citizens and devices was 37.88+/-5.78 m^3/s.

4.3.3. Data acquisition and processing

The DApp is connected to a cloud-based database that stores the measurements and to a web-based dashboard that allows easy data and site management. The DApp does all the processing in the phone, besides the steps described in the previous section the user does not have to do anything else. After each measurement, the results and a proof image can be uploaded and visualized via the web application in one click, ensuring an error free, fast and secure data collection.

4.3.4. Troubleshooting

The input data is minimal: GCP's world coordinates, cross-section and river bed roughness. However, those measurements have to be accurate, otherwise they are sources of error. One of the most common problems is that GCP coordinates are not measured in / typed in properly.
In slow-flowing canals or rivers, any small movement on the smartphone while it is recording will also introduce errors in the velocity calculation. Therefore, it is recommended to use a tripod, especially in low flow.

4.3.5. Advantages and Limitations

The DischargeApp provides a very cost-effective solution to gather data in data-scarce regions, the only thing needed is a smartphone, and because of that it is vandalism free. Its use is very simple to use, there is no need for expert knowledge. Since the DischargeApp is connected to a cloud-based database, the data transmission is error free and can be accessed via a web application.

This technology relies on structures on the surface of the water which are moving at the same speed as the water flow to measure the water velocity. Hence, it is challenging to measure in slow-flowing water courses and in some cases not possible. Strong winds can create waves on the surface of the water, which are not travelling at the same speed as the flow, hence care should be taken to avoid taking measurements during strong winds.

The DApp can be installed on any Android smartphone via the Play Store.

5. Conclusions

This Innovation Snapshot has provided an overview of non-contact technologies for hydrometry, highlighting their advantages over traditional contact-based methods through the exploration of general principles and of three specific technologies: the Riverlabs UK lidar-based water level sensor, OpenRiverCam, and the DischargeApp.

The main advantage of non-contact technologies is their ability to gather hydrometric data remotely, eliminating the need for the instrument to be in physical contact with water. This not only ensures increased safety for field personnel but also minimizes disturbances caused by debris or hard conditions of the watercourse, allowing monitoring of hard-to-access areas and improving the reliability of data streams.

One of the advantages of the Riverlabs UK lidar-based water level sensor is its flexibility, as the solution can easily be adapted to different use cases. Also, the technology presents lower costs compared to other existing non-contact water level technologies, and it is particularly suited for application in remote regions, rivers with unstable riverbeds, and little to no infrastructure.
Some of the innovative aspects of OpenRiverCam are 1) its automated workflow, 2) the fact that users anywhere can perform the analysis, also without access to high-performance computing equipment, and 3) the fact that there are no costs associated with the use of the software as all steps are covered by open-source software.
Smartphone-based methods, such as the DischargeApp, enable cost-effective and user-friendly hydrometric measurements due to the widespread availability of smartphones, allowing also non-experts in the field to collect data.

It is, however, important to acknowledge that there are still limitations and challenges associated with the implementation of non-contact technologies, such as environmental factors, their limited applicability, and barriers to their adoption. Further exploration, adaptation and integration of these technologies into existing hydrometric practices are needed for their widespread adoption and implementation, which can help promote more efficient and comprehensive water monitoring and improved water resource management.

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