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Flood Prediction using High-Precision GNSS

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Summary:
Globally, climate change has accelerated extreme weather and floods have become more frequent. The traditional water level measuring stations are old, invasive and have limited capability in terms of telemetry. Because of the unavailability of a proper warning system, the floods have caused numerous deaths. WAMO 300 provides an innovative and non-invasive way of measuring water levels that uses Navigation satellites such as GPS or Galileo to provide real-time warnings to the various stakeholders.

Keywords: GNSS, RTK, Flood, Water level monitoring, Environmental monitoring

FLOOD PREDICTION USING HIGH-PRECISION GNSS

Background, Motivation and Objective

In mid-July 2021, climate change-related flood disasters occurred in Germany, with North Rhine-Westphalia and Rhineland-Palatinate the worst affected. During the night, the rain caused massive flooding, leading to socio-economic impacts, which amount to up to 180 presumed deaths and infrastructure damage in the billions [1].
Despite sufficient warning systems, such as a nationwide system of precipitation radar stations, the disasters occurred due to a lack of measures and equipment in civil protection [1].
WAMO-300-system (Water Monitoring) is the first all-in-one real-time surface water assessment platform that will provide real-time monitoring and timely alerts to the various stakeholders such as water authorities, firefighters and the common people that will help take timely action and reduce losses.

Satellite Navigation System

When satellite constellations are used for positioning or time service, it is called a Navigation satellite system. Based on the coverage, they can be classified as either GNSS (Global navigation satellite system) or RNSS (Regional Navigation Satellite Service) for regional coverage [3].

D-GNSS and RTK

As the signal travels from space, various factors, e.g. ionospheric delay or multipath, might result in errors. To reduce it, various techniques are used, such as WAAS (Wide Area Augmentation System), GBAS (Ground Based Augmentation System), EGNOS (European Geostationary Navigation Overlay Service) or D-GNSS (Differential-GNSS). D-GNSS uses a reference station whose position is fixed and known. So when the satellite signal reaches the base station, it knows the error in calculated pseudo-ranges. It then broadcasts this correction locally, and a receiver station may correct its calculations by this amount.

The accuracy of the resulting range measurement is essentially a function of the ability of the receiver's electronics to accurately process signals from the satellite. To avoid this, RTK (Real Time Kinematic) uses the satellite signal's carrier wave as its signal, ignoring the information contained within.

The base station re-broadcasts the phase of the carrier that it observes, and the mobile units compare their own phase measurements with the one received from the base station. The range of a satellite is essentially calculated by multiplying the carrier wavelength times the number of whole cycles between the satellite and the rover and adding the phase difference. Thus, providing up to centimetre-level accuracy [3].

The WAMO 300 system

WAMO 300 is a self-sustainable movable floating platform with a GNSS receiver connected to it, which allows us to calculate the water level. The usage of the U-Blox C94-M8P RTK-based sensor for water level monitoring is

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the innovation point. As soon as the rover receives a correction message, it changes to RTK Float mode. In this state, the accuracy is at the decimeter level. When the Dilution of Precision is below 100, the rover enters RTK Fixed mode. In this state, the accuracy is at the centimeter level.

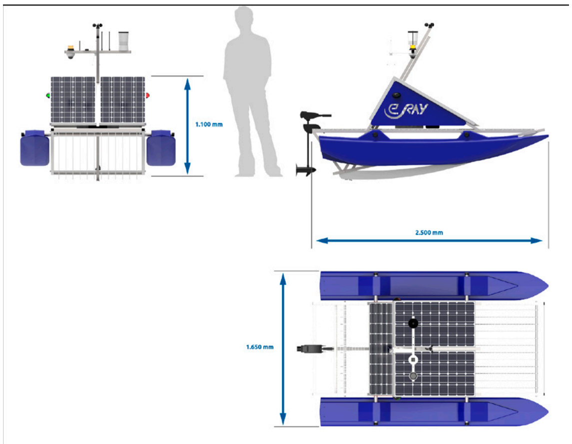

Fig. 1: Different viewpoints of WAMO 300, measurements: 2500 mm x 1650 mm x 1100 mm

The power supply is composed of three 100-120 W solar PV modules that provide power autonomy and have an energy management system with 3.8 - 24 V DC/AC, wired in the marine standard for on-board safety. The communication system offers the options GSM, LTE, LoRa, Wi-Fi, as well as Satellite Communication such as SWARM Technologies Two GNSS receivers with RTK capability are used in base-rover pair to measure water level with centimeter precision (± 2500 mm).

Furthermore, the device allows the integration of other sensors, such as temperature sensors, to record atmospheric and water temperature as well as the internal system temperature. It also measures the parameters of the built-in battery management system (BMS) for safety measures.

The innovative design allows fast integration, flexible installation and easy maintenance.

Experiment Setup and Goal

The tests took place in the Woog lake in Darmstadt, in partnership with the Darmstadt city authority. The experiment's goal was to demonstrate the system's capability in a near-real-life scenario and to demonstrate the availability of the system over a long period. The observations during this period would be used to improve the further functionality of the system.

Observation

Total number of days - 79

Total readings - 107929

Tab. 1: Real Time Kinematic availability rate

RTK Status	Total count	Relative amount of counts [%]
RTK Fixed	92177	85.4
RTK Float	8078	7.5
No RTK	7674	7.1

As can be seen in the table above, The system was in RTK Fixed mode for 85.4% of the time. Further, RTK Float mode availability increases the uptime to 92.9 %. The No RTK mode was observed because of electrical faults in the base station. It can be mitigated by proper electrical installation and thus increasing the availability further.

Prospect

The next step involves developing algorithms to predict floods based on real-time data provided by WAMO.

In the future, the WAMO 300 platform will be further developed. Usage of Dual Band GNSS chips such as C099-F9P may further increase the accuracy of measurements in RTK Float mode or even when there is no RTK message.

The flexibility of the system to accommodate additional sensors further increases the system's potential. WAMO's measurements can be used to establish models for understanding potential changes in water quality and monitoring surface water conditions.

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