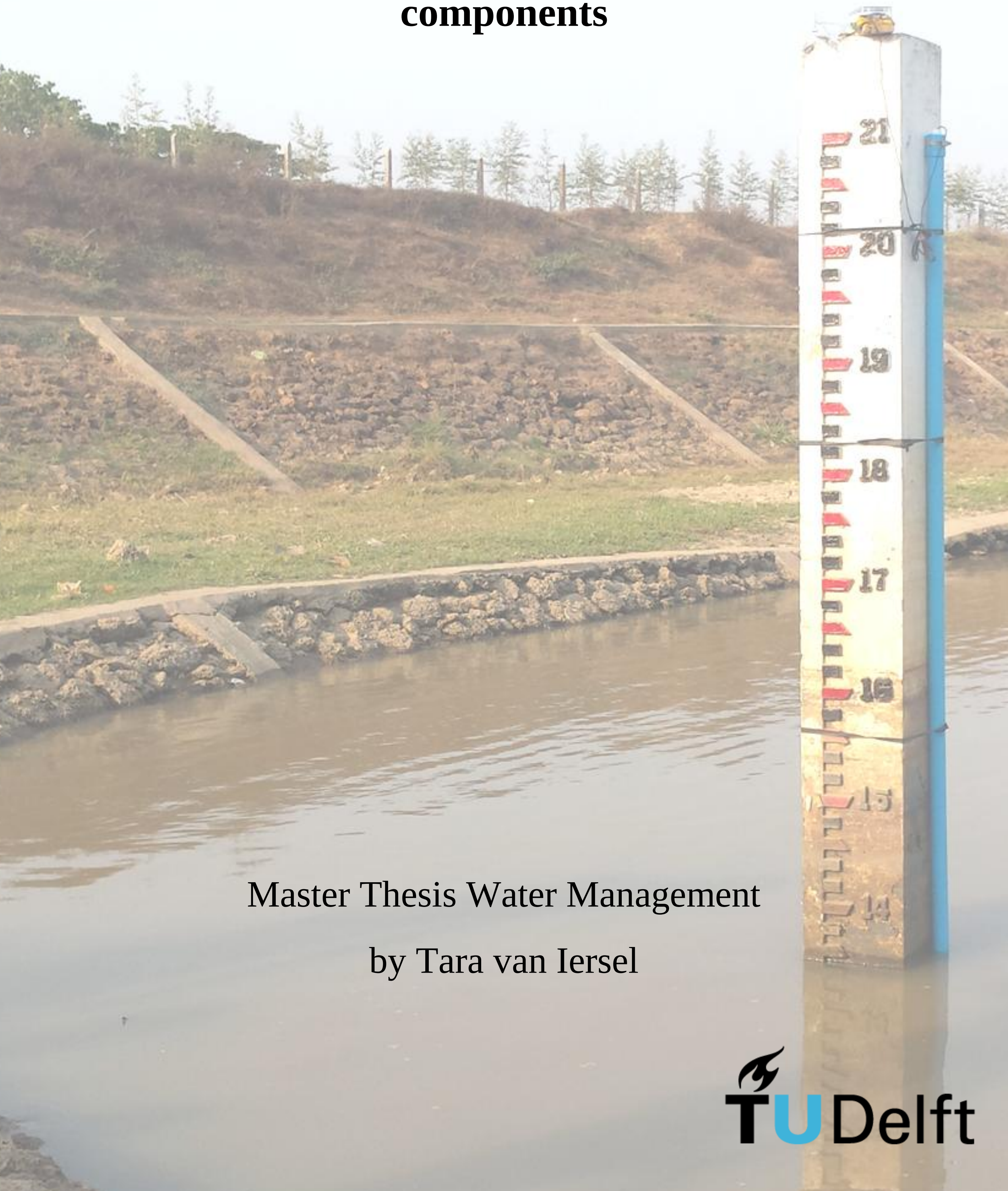
Prototype low cost acoustic automatic online water level sensor made from off the shelf components



Master Thesis Water Management

by Tara van Iersel

TU Delft

Prototype low cost acoustic automatic online water level sensor made from off the shelf components

T.A. van Iersel

Master thesis as part of the requirements of the Master of Science Water Management

Delft University of Technology

Publicly defended on Wednesday August 30, 2017 at 16:00

Student number: 1373676
Thesis committee:
Department of Water Resources, TU Delft
    Dr. ir. O. A.C. Hoes
    Dr. ir. R.W. Hut
    Chair: Prof. dr. ir. N. C. van de Giesen
Department of Technology, Policy and Management, TU Delft
    Dr. ir. J.S. Timmermans

Acknowledgments

This article was made as part of the thesis of the master Water Management at the Faculty of Civil Engineering at Delft University of Technology.

I would like to thank Partners for Water and the Lamminga Fund for supporting this research.

I would also like to thank all my committee members, Olivier Hoes thank you for creating the opportunity for me to do this research. The combination of the practical side of this research, my stay in Myanmar and the freedom to make this research mine made this the best part of my studies in Delft. Thank you Rolf Hut for helping throughout the whole process from soldering to learning me how to lay-out my article. Thank you to Nick van de Giesen for being my thesis chair and for your feedback on my article and thank you Jos Timmermans for your interest in my research and joining my committee at a later stage.

To my parents, sisters, brother, Chris, nephews and Lodewijk I would like to thank you all for helping where possible throughout the whole period in Delft. Thank you Martijn for your support and helping with the dirty work in the field and lab.

I would also like to thank the members of the Dispute Water Management for making the past two years as fun as possible. With special thanks to Cara, my cycling and study buddy.

Tara van Iersel, August 2017

Manuscript prepared for Geosci. Instrum. Method. Data Syst.
with version 2014/09/16 7.15 Copernicus papers of the LaTeX class copernicus.cls.
Date: 23 August 2017

Prototype low cost acoustic automatic online water level sensor made from off the shelf components

T.A. van Iersel[1], **O.A.C. Hoes**[1], **and R.W. Hut**[1]

[1]Delft University of Technology, Water Resources Section, Stevinweg 1, 2628 CN Delft, the Netherlands

Correspondence to: T.A.van Iersel (tavaniersel@gmail.com)

Abstract. Water level data is a key factor in water systems research. Frequently measuring water levels in areas with tidal influence is especially desirable because it enables observations to follow the rise and fall between minimum and maximum water level. However, a majority of developing countries are not able to measure water levels at the desired time stamp and spatial scale with currently available water level measuring instruments, predominantly due to limited financial resources. Countless reliable instruments exist that measure water levels, although low-budget instruments are few and far between. Literature study showed that the price of water level instruments are not representative of the water level measurement accuracy acquired.

This research focuses on the need for a water level measuring instrument that is low cost, automatic, reliable and suitable for use in developing countries, specifically in Myanmar. In Myanmar, automated water level data collection remains challenging due to limited financial resources. This data collection limitation inhibits Myanmar's ability to optimize the distribution of water resources, potential consequences of poor water resource management include floods and droughts. Key requirements for a water level gauge to be considered suitable for use in developing countries include, simple to operate and repair, made from off the shelf components and operational in remote areas.

We developed an automatic water level gauge incorporating an acoustic distance sensor, which is the type of sensor used for parking assistance in modern cars. To validate the applicability of our instrument, field trials were undertaken in The Netherlands and Myanmar. Our research objective was achieved and therefore we demonstrated it is possible to build a water level measuring instruments that is cost-efficient, automatic, reliable and suitable for use in developing countries. Although tests results from the Netherlands are promising, further optimization is needed for deployment in Myanmar.

---

1 Introduction

Water level data is an important consideration for informed water management decision making. In a water system, water level data is often used in flood mitigation studies and to optimize the distribution of water resources.

When a new structure in or near a waterway is designed, the water level fluctuation is one of the design boundary conditions. Especially in areas with tidal influence it is desired to measure with a time stamp that allows to follow the rise and fall between maximum and minimum water levels. Water level monitoring also enables early detection of short or long term trends, in the behavior of water systems. Information supply which, for example, is important for shipping will be improved by early detection. Water level data is also a key input for models of the water system. In hydrology water level measurements indirectly provide information about discharge, based on the stage-discharge relation.

Some developing countries are not able to measure water levels at the desired time stamp and spatial scale with current water level measuring instruments due to limited financial resources. At present, there are countless instruments that measure water level reliably, although low-budget instruments are few and far between. The objective of this research is to develop an automated instrument to measure water levels with a focus on deployment in Myanmar. The main design criteria for our instrument are that it is cost-efficient, simple to operate, repair and made of off the shelf components which is operational in remote areas, without external power source and with cellular connectivity.

Section 2, will elaborate on existing water level measuring techniques. Section 3 introduces the case study site, the area around Bago in Myanmar. The introduction of how our instrument measures the water levels is in Section 4, followed by the description of the test sites in Section 5. Results of fieldwork in the Netherlands and Myanmar will be presented and discussed in Section 6, followed by recommendations for further steps in Section 7.

2 Existing water level measuring techniques

Various instruments have been used to measure water levels, the instruments can be characterized in instruments that make use of direct methods or inferential methods. In the direct method the water level directly follows from sight or from a part of the sensor that is located at the water level. In the inferential, or indirect, methods no part of the sensor is located at the water level. The oldest instruments make use of the direct method, a staff gauge is a good example of this.

Another sensor which makes use of the direct method is the float sensor. A float is located at the water surface, the exact location can be transmitted in various ways. E.g. a wire and pulley convert the water level fluctuations to an angular displacement that can be translated into a water level change (Hartong and Termes, 2009), here the location of the, magnetic, float is found by using the speed of a torsional wave along a wire (Roy, 1994). Float sensors are commonly used and advantageous since they are not affected by turbid water, fluctuations in water or air temperature and are capable of withstanding freezing temperatures.

Probe based instruments also belong to the direct method for measuring water levels. Probe based instruments rely on the liquid as a conductor. Instruments that use the Time Domain Reflectometry (TDR) technique to measure water levels have a probe installed vertical in a pipe in the water body. From the top of the probe, an, in this case, electromagnetic pulse is generated that propagates down. Where the probe enters the water part of the pulse will be reflected back. The time taken for the pulse to propagate from transmitter to reflect back is measured, this time is proportional to the distance between the sensor and the target (Moret et al., 2006). This technique has a high accuracy and reliability.

Other measuring instruments are based on the inferential method, such as submersible hydrostatic sensors. Submersible hydrostatic pressure sensors operate based on Pascal's principle, liquid exerts equal pressure in all directions. The water pressure increases linearly with increasing water depth. Pressure sensors measure water pressure at a certain depth and compare this with the atmospheric pressure measured at the same time (Moret et al., 2006). Pressure sensors are often used because they are easy to install, submerged out of sight and have low power requirements, although a few disadvantages including poor functionality in freezing or highly turbid water and vulnerability to inaccuracy when water temperature fluctuates.

Another type of submerged hydrostatic pressure sensors is the bubbler sensor. Bubbler sensors measure water levels with air-filled tubes or chambers with open submerged bottom ends. The water level is determined by measuring the pressure required to push a bubble through the end of the tube or chamber. The higher the water level, the higher the hydrostatic pressure and therefore a higher pressure is required in the tube or chamber (Roy, 1994) (10). Bubbler sensors are easy to install and not affected by air or water temperature fluctuations or turbid water. All submerged hydrostatic pressure sensors are affected by density of water which leads to a deviation of the correct water level in brackish or saline water due to a higher density of the water.

In addition to measuring water pressure, Conductivity, Temperature and Depth (CTD) sensors also measure conductivity and temperature of water. With conductivity, the salinity can be computed which enables CTD sensors to correct the water level in saline water. CTD sensors are more reliable than other submerged hydrostatic pressure sensors when used in saline water, but also more expensive.

Other common instruments which make use of the inferential method are measuring instruments sensing the water surface with a downward looking sensor. Downward looking sensors measure the time between sending a, light, radar or sound, pulse from a fixed location above the water surface and receiving the reflected pulse, the pulse is reflected by the water surface. Ultrasonic downward looking sensors use sound waves with a frequency around 20 to 80 kHz. Laser downward looking sensors use the speed of light. Hernandez-Nolasco et al. (2016) and Alsdorf et al. (2000) studied the downward looking radar. Water levels monitored with a micro wave radar sensor are highly accurate and stable despite humidity and temperature changes.

All instruments described throughout this section have varying advantages and disadvantages, the accuracy of all sensors are sufficient for the application of this study. It is interesting to note the contrasting cost of sensors and the subsequent observation that price is not an indication of the water level measurement accuracy acquired from the instruments.

The floater and hydrostatic instruments exist with manual or automated data collection. With automated data collection the price of the instruments rapidly increases. All automated instruments with advanced communication capabilities require micro-controllers to read out the sensors, locally log and transmit the data. Advanced technology instruments, such as the downward looking instruments and TDR-instruments, are highly reliable and expensive. Due to the costs all earlier described instruments are not suitable for deployment in developing countries on a large scale.

The need for a low cost and reliable method to measure and collect water levels was also noticed by Overloop (2013), leading to the Mobile Level Tracker. Mobile Level Tracker focuses on measuring water levels in developing countries and makes use of a mobile phone: a picture with a geo-tag is made and automatically uploaded to a database, here the picture is converted to a water level at a certain location and time. This method is typically inexpensive and easy to use but has the drawback that it is labor intensive or measurements may be irregular in time and space. Kruger et al. (2016) developed a sensor for measuring river and stream stages from bridges. The relative low costs and robustness of the sensor contribute to a more widespread deployment, for developing countries it remains too costly to install and maintain on a large scale.

3 Water levels in Myanmar

In terms of water resources, Myanmar is an interesting country. Myanmar independently controls most of its water resources, which consists of a low lying delta and a large river system where three out of four national rivers flow within the borders of the country (The Dutch Min. of Foreign Affairs, 2015). Myanmar has sufficient water resources, in theory, to sustain its population. With reservoirs and dams, the government strives to find a balance between retaining water in the dry season and preventing floods in the wet season, while making use of the water for irrigation, drinking water and hydropower (Burki, 2015)(MOAI, 2015).

Since Myanmar opened its borders, the economic growth of the country increased rapidly. In April 2016, Myanmar was declared world's fastest-growing economy, according to IMF (2016). The growing economy enables and requires vast opportunities in terms of improving water management (Van Dijk, 2014). Optimizing the interrelation between sluices to maximize hydropower whilst achieving its full potential in terms of water safety and irrigation would make Myanmar better able to manage issues they presently encounter. Water level measurements are a key factor for informed decision making in water resource management.

Data collection is, however, still challenging due to limited financial resources. One of the many data collecting departments, the Department of Meteorology and Hydrology (DMH) of the Ministry of Transport measures at 115 locations throughout Myanmar. Water levels are measured manually one to three times per day, depending on whether it is the dry or wet season. At four locations, which are influenced by tide, measurements are undertaken with a higher frequency by DMH to monitor the tides. DMH makes use of automated water level gauges at these locations. Despite high costs the success of these automated water level gauges is low due to various reasons such as broken sensors or incorrect results from a pressure sensor in saline water. All other manual water level gauges are easy to implement, although they are highly labor intensive and frequently measuring at all desired locations is still too costly.

4 Method

Based on the need for a low cost and reliable method to measure and collect water levels automatically in Myanmar, an instrument has been developed. Our instrument is an automatic water level gauge which utilizes an acoustic distance sensor, it determines the distance between a reference point and the water level. The distance is corrected with the measured air temperature and the data is sent via the mobile network to an online database and logged on a SD-logger. In figure 1 the sensor scheme is shown. The sensor scheme and code that are used for our sensor can also be found on https://zenodo.org/badge/latestdoi/101153659.

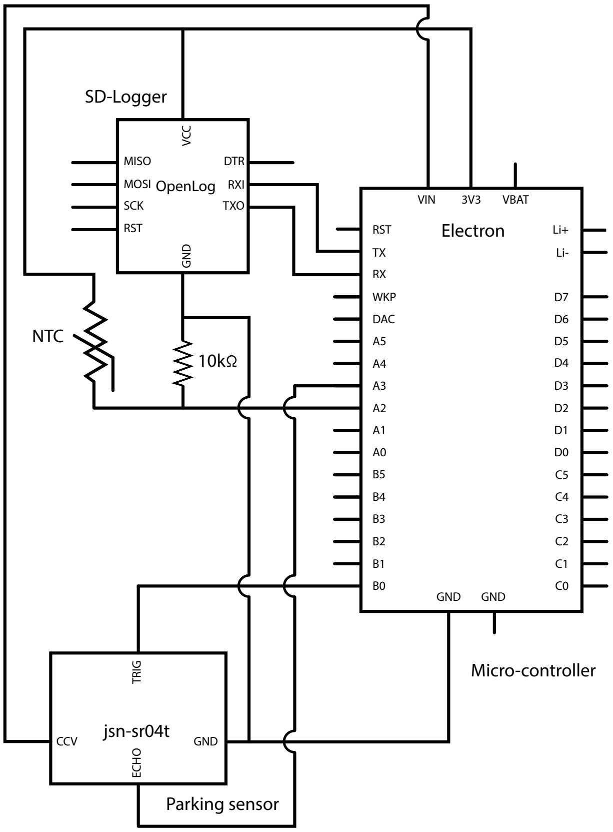


Figure 1. Sensor scheme

4.1 Distance sensor

The acoustic sensor is installed at a fixed point above the water, from here it transmits an acoustic signal which will be reflected by the water surface. From the time interval between sending the signal and receiving the reflected signal the distance to the water level is calculated with the speed of sound in combination with the air temperature in the tube. The air temperature through which the ultrasonic sensor measures the distance is important, because the velocity of the ultrasonic waves through a medium is related to temperature of that medium and inversely related to density. The relationship between the velocity of the ultrasonic waves, v_w (ms^{-1}), and the temperature of the medium, T (K) can be described by Eq. 1 (Malek et al., 2012).

$$v_w = \sqrt{\frac{\gamma RT}{M}} \qquad (1)$$

Figure 2. Sensor set-up

Test site	Country	Latitude Longitude
Maassluis	The Netherlands	51°54’57.3"N 4°14’49.1"E
Scheveningen	The Netherlands	52°05’47.8"N 4°15’57.4"E
Mazin reservoir	Myanmar	17°20’32.5"N 96°26’16.8"E
Old B-S Channel	Myanmar	17°13’02.5"N 96°29’52.3"E
New B-S Channel	Myanmar	17°12’56.3"N 96°29’53.8"E
Bago river	Myanmar	17°13’01.2"N 96°29’51.0"E

Table 1. Test location coordinates

Where γ is the heat capacity ratio, the ratio between the heat capacity at constant pressure (c_P) and the heat capacity at constant volume (c_V), $\gamma = \frac{c_P}{c_v}$. In this research it is assumed to be 1.4. R is the molar gas constant, 8.3144598 $Jmol^{-1}K^{-1}$ and M is the molar mass of the air, for our instrument it is assumed to be 28.965 $Kgmol^{-1}$.

The distance sensor is the waterproof JSN-SR04T with an acoustic emission frequency of 40 kHz and a reach between 25 and 450 cm. It is a common sensor used in the car industry for parking assistance. The sensor uses 5 V and communicates via trigger and echo with digital pins on the micro-controller. The trigger pin first gives a high-level, then the module starts ranging. When the impulse is reflected back the echo pin will become high level.

4.2 Temperature sensor

For the temperature measurements a waterproof negative temperature coefficient (NTC) thermistor with a resistance of 10 $k\Omega$ was used. The resistance of NTC thermistors decreases with increasing temperatures. The temperature sensor is connected to 3.3 V, in series via a 10 $k\Omega$ resistor to ground and between the two resistors to an analog pin on the micro-controller. The Steinhart-Hart Equation determines the temperature from the resistance ratio between the resistor and the temperature sensor (Steinhart and Hart, 1968). It can measure temperatures between $-20°C$ and $105°C$.

4.3 SD-logger

In addition to the online database, data is saved with a SD-logger on a micro SD-card, in case the mobile network is down. The SD-logger that is used is the SparkFun OpenLog. The VCC input can be between 3.3 and 12 V. In this case a VCC input of 3.3 V is used, further is it connected to ground. TXO output is connected with the RX pin of the micro-controller and RXI input is connected to the TX pin of the micro-controller. The SD-logger writes the data on a micro-SD card of 16 GB and uses between 2 mA during rest and 6 mA during maximum recording rate.

4.4 Micro-controller

The signal from the acoustic sensor and the temperature sensor is processed into a water level on a micro-controller. The micro-controller with cellular service, Electron model SARA-U270 from the brand Particle, gives the command to measure water levels every two minutes. The water levels are sent to an online database after five measurements via the mobile network. With the command Particle.publish() data can be sent from the micro-controller to Google drive. In addition, data is saved on the micro-SD card, in case the mobile network is down. The code used for this can be found on https://zenodo.org/badge/latestdoi/101153659.

4.5 Power system

The micro-controller is standard equipped with a 2000 mAh battery. Our sensor is expanded with a power bank of 2600 mAh. The standard 2000 mAh battery is required to jump in if the power consumption of the micro-controller exceeds what can be delivered via USB. In Myanmar the power bank was connected to a 2 Wp solar panel. At other locations with varying solar energy a different solar panel might be needed.

4.6 Set-up

Our sensor uses a PVC tube that is attached to a vertical construction in the water see Figure 2. To test the influence of the diameter of the PVC tube a variety of diameters are used between 50 and 125 mm. A lid is placed at the lower end of

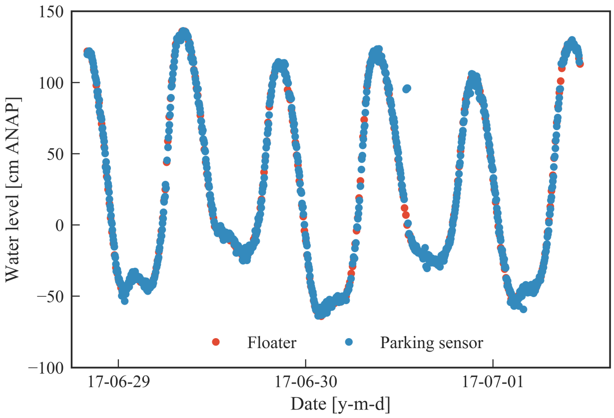


Figure 3. Water level Maassluis

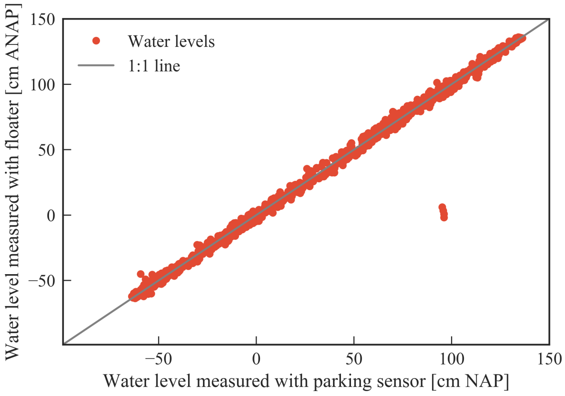


Figure 4. Linear regression Maassluis

the pipe and a few small holes are made. Due to these small holes, the water level in the tube is connected to the water level of the water body, water level fluctuations caused by small waves in the water body are damped in the tube. A lid with the sensor is placed on the top of the tube. After the distance between the ultrasonic sensor and the water surface is measured the water level can be calculated by subtracting the measured distance from the reference point with respect to mean sea level. The reference point is the height of the sensor with respect to mean sea level.

5 Description of test sites

5.1 Test sites in The Netherlands

Our sensor is made and tested at two locations in the Netherlands. The gauges in the Netherlands were located in the harbors of Maassluis and Scheveningen in the province Zuid-Holland, see Table 1 for the latitude and longitude. Both locations are strongly influenced by the tide with an average water level fluctuations of 283 cm in Maassluis and 313 cm in Scheveningen (Netherlands, 2017). In Maassluis a tube with a diameter of 110 mm is used and in Scheveningen a tube with a diameter of 125 mm is used. The Dutch Min. of Infrastructure and Environment, measures water levels every ten minutes in both harbors. The Dutch Min. of Infrastructure and Environment measures these water levels using an automated float sensor and publishes the data on internet via https://waterinfo.rws.nl/ # !/kaart/waterhoogte-t-o-v-nap/.

5.2 Test sites in Myanmar

To study the usability and accuracy in Myanmar measurements were carried out at four locations in the state Bago in Myanmar. Locations were chosen to represent different tidal and river regimes. The first location is the Mazin reservoir located in the city Bago where water is stored for flood prevention and suppled as drinking water to Bago and irrigation water for farms. The other locations where close to each other in the village Tawa (or Tarwa), gauge two is placed in the old Bago-Sittaung irrigation channel constructed in 1878. Table 1 gives the latitude and longitude of all measurement locations. In 2014, the Bago-Sittaung irrigation channel was renovated. It protects around 70.000 people from floods and supplies irrigation water for paddy fields in the area. With the renovation the downstream end is split in two channels, a new sluice gate is build in the new downstream end. Gauge three is placed in the new Bago-Sittaung channel next to the new Tawa sluice gate. The fourth gauge is placed downstream of the old Tawa sluice gate in the Bago River, see Table 1. In Myanmar at all locations a tube with a diameter of 50 mm was used.

6 Test results and discussion

6.1 Results from The Netherlands

In Figure 3 the water levels at the harbor of Maassluis are presented in cm ANAP. ANAP is Above Amsterdam Ordnance Datum. The blue dots present the water levels measured with the parking sensor and the red dots the water levels measured by the floater sensor from the Dutch Min. between the 25th of June and the 1st of July 2017. As can be seen the water level measurements with the parking sensor follow the measurements of the floater sensor closely. For a short period the parking sensor measured a water level 100 cm higher than the floater sensor.The water levels measured with the floater sensor are interpolated to the exact time stamp in which the parking sensor measured to make a regression plot, see Figure 4. The red dots on the x-axis show the water levels measured by the parking sensor and on the y-axis the water levels measured with the floater sensor at the same time. The linear regression shows a good correlation between water levels retrieved with both sensors. Around a water level of 100 cm

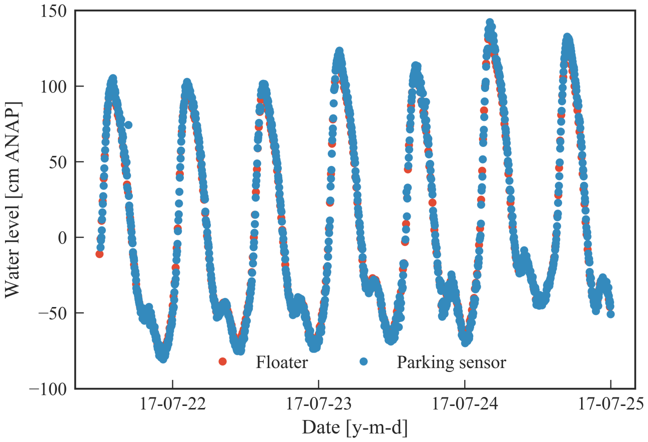


Figure 5. Water level Scheveningen

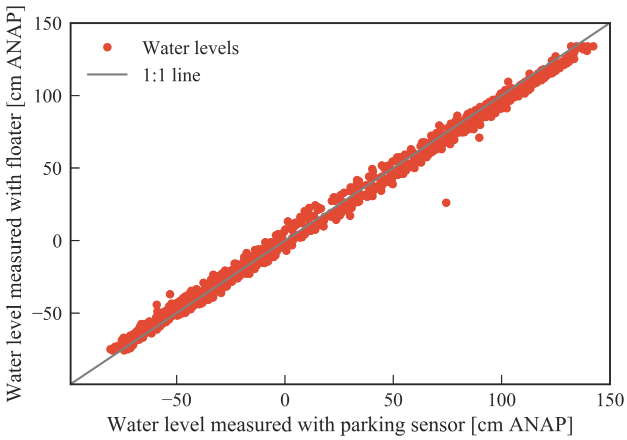


Figure 6. Linear regression Scheveningen

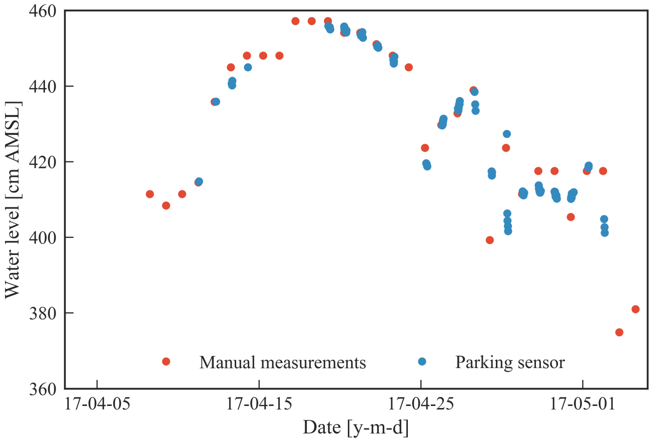


Figure 7. Water level New Irrigation Channel

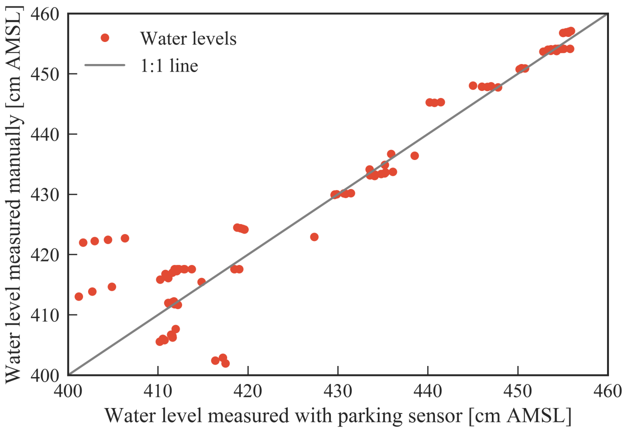


Figure 8. Linear regression New Irrigation Channel

above NAP the parking sensor experiences some noise, this can be due to irregularities in the PVC tube.

Figure 5 shows the water levels at the harbor of Scheveningen between the 19th and 26th of July 2017. The water level measurements from the two sensors follow each other closely. Figure 6 presents the linear regression of the water levels measured in Scheveningen. Besides minor noise the linear regression gives a strong correlation between both sensors.

6.2 Results from Myanmar

In Myanmar measurements were carried out at four locations. The measurements at the four locations showed similar results here we present the results of one location, the New Irrigation Channel. This location was chosen because the parking sensor collected the most date here. Figure 7 presents the water levels in cm Above Mean Sea Level (AMSL) at the New Irrigation Channel between the 6th of April and the 10th of May 2017. The blue dots present the water levels measured with the parking sensor and the red dots the water levels measured manually by the Min. of Agriculture, Livestock and Irrigation of Myanmar. The water level measured with the parking sensor experiences noise which leads to deviating water levels from the manual measured water levels. Compared to the measurements in the Netherlands the noise increased, this is supposedly due to the smaller diameters of the PVC pipe. When the parking sensors does not experience noise the water levels measured with both methods follow each other. In addition to the noise problems with the power supply are noticed. Due to the high temperatures in the sensor the power bank was not working accordingly which lead to missing data several hours a day. Figure 8 presents the linear regression of the water levels measured in the New Irrigation Channel.

6.3 Lab tests

The accuracy of the parking sensor is tested in the lab by measuring twelve times at the same distance to the water

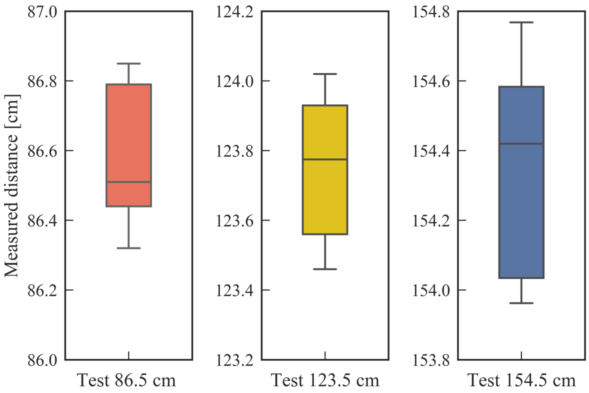


Figure 9. Boxplot lab tests

level. Three tests are carried out, at a distance of 86.5 cm, 123.5 cm and 154.5 cm. The results are shown in a boxplot in Figure 9. In the lab optimal conditions lead to a high accuracy of the parking sensor, the accuracy of the sensor decreases with the measured distance.

7 Conclusion and recommendations

The objective of this research was to develop a cost-efficient, automatic and reliable water level measuring instrument, suitable for use in developing countries. Trials undertaken in The Netherlands validated that it is possible to build an instrument from off the shelf components that automatically collects reliable water level data whilst remaining inexpensive. While there were some promising results in Myanmar, further improvement of the instrument is needed to be suitable for these conditions. The most important advantage of our instrument is the combination of low cost, off the shelf components, and the ability to collect data automatically.

Without sacrificing the strong points of the instrument, such as the cost-efficient parking sensor, there is room for improving its reliability and robustness. In this research various diameters were used for the PVC tube, larger diameters decrease the change of noise measurements. For further study we recommend to use larger diameters to increase the reliability of our sensor or to test the sensor without a tube.

In Myanmar measurements were influenced by issues with the power supply, caused by high temperatures in the closed environment of the instrument in combination with the power bank which was observed not to be able to cope with high temperatures. For deployment in Myanmar we recommend trialling alternative configurations with the existing power bank and/or seeking temperature resilient power banks in order to overcome power bank temperature issues.

This work was our start towards creating water measuring instruments that are suitable and accessible for developing countries on a large scale.

Acknowledgements. This work was performed under support from Partners for Water. The authors would like to thank Director Zaw and Sai Wunna from the Irrigation Technology Centre and Director Khon Ra and Dr. Aung Than Oo from the Hydrology Branch in Myanmar. The authors would like to recognize Director Zaw Lwin Tun of the Ministry of Agriculture, Livestock and Irrigation for bringing the problem to our attention.

References

Alsdorf, D. E., Melack, J. M., Dunne, T., Mertes, L., Hess, L., and Smith, L. C.: Interferometric radar measurements of water level changes on the Amazon floodplain, Nature, 404, 174–177, 2000.

Burki, T.: Floods in Myanmar damage hundreds of health facilities, The Lancet, 386, 843, doi:10.1016/S0140-6736(15)00004-5, http://dx.doi.org/10.1016/S0140-6736(15)00004-5, 2015.

Hartong, H. and Termes, P.: Handboek debietmeten in open waterlopen., pp. 1–254, http://agris.fao.org/agris-search/search.do?recordID=NL2012045275, 2009.

Hernandez-Nolasco, J. A., Ovando, M. A. W., Acosta, F. D., and Pancardo, P.: Water Level Meter for Alerting Population about Floods., 2016 IEEE 30th International Conference on Advanced Information Networking & Applications (AINA), p. 879, http://stcproxy.han.nl/han/hanquest/search.ebscohost.com/login.aspx?direct=true{&}db=edb{&}AN=116446097{&}lang=nl{&}site=eds-live, 2016.

IMF: Too Slow for Too Long, 2016.

Kruger, A., F. Krajewski, W., J. Niemeier, J., Ceynar, D., and Goska, R.: Bridge-mounted river stage sensors (BMRSS), IEEE Access, PP, 1, 2016.

Malek, N. I., Ijardar, S. P., Master, Z. R., and Oswal, S. B.: Temperature dependence of densities, speeds of sound, and derived properties of cyclohexylamine + cyclohexane or benzene in the temperature range 293.15-323.15 K, Thermochimica Acta, 547, 106–119, doi:10.1016/j.tca.2012.08.011, http://linkinghub.elsevier.com/retrieve/pii/S0040603112003991, 2012.

MOAI: MYANMAR Climate-Smart Agriculture Strategy, 2015.

Moret, D., Arrúe, J. L., López, M. V., and Gracia, R.: A new TDR waveform analysis approach for soil moisture profiling using a single probe, Journal of Hydrology, 321, 163–172, doi:10.1016/j.jhydrol.2005.07.041, http://linkinghub.elsevier.com/retrieve/pii/S0022169405003847, 2006.

Netherlands, I. B. M.: Rijkswaterstaat Waterinfo, https://waterinfo.rws.nl/{#}!/kaart/waterhoogte-t-o-v-nap/, 2017.

Overloop, P. J. van, K. R. K. W. V. M.: Mobile Canal Control, an automatic administration system for manual canal operations using smart-phone Technology, USCID-Proceedings Seventh International Conference on Irrigation and Drainage, Phoenix, Arizona, 2013.

Roy, G. J.: Notes on Instrumentation and Control (Marine engineering), Marine Engineering Series, Elsevier Science, https://books.google.nl/books?id=efL8BAAAQBAJ, 1994.

Steinhart, J. S. and Hart, S. R.: Calibration curves for thermistors, Deep Sea Research and Oceanographic Abstracts, 15, 497–503, doi:10.1016/0011-7471(68)90057-0, http://linkinghub.elsevier.com/retrieve/pii/0011747168900570, 1968.

The Dutch Min. of Foreign Affairs: Urban water in Myanmar, pp. 1–4, 2015.

Van Dijk, T., C. A. H. R.: An engineer's paradise, 2014.

TUDelft