Personal experimental project
Monitoring the failure of fluvial dikes

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1 Introduction

Dike breaching is one of the major issues in dike sizing. The risks of such events must be carefully examined, either for constructing new dikes or reshaping old ones. For that sake, a detailed understanding of the mechanisms of dike breaching is of highest importance; but for safety and cost reasons, only experiments on small scale models can be carried out. The experimental dike must be monitored during the whole experiment, by means of laser profilometry in general. However, this method being expensive and quite complex to set up, this research aims at seeking other methods for measuring depth, e.g. the Kinect V2 of Microsoft which is cheap and easy to set up.

2 Statement of the problem

While a lot of researches has been conducted on how Kinect V2 behaves in air, it is novel to consider using its depth sensor to monitor objects, like dike breaches, under the water surface. There are real challenges to using a Kinect in such conditions, including reflection, refraction and sensor calibration. There is also a lot of noise that adds up, due to impurities in water and not-smooth water surface.

3 Objectives

This research will focus on finding simple models to understand better the main issues about using a Kinect for underwater screening. Then, simple algorithms will be sought to reduce noise and errors linked to the aforementioned physical phenomena. The sensor will also be tested for different materials -still underwater- exhibiting different diffusive and reflective coefficients.

4 Plan of action

First, it will be necessary to quantify the significance of the physical phenomena. As seen in Figures 1 and 2, the measured depth changes as a function of the level of water above the sample. Surprisingly, preliminary experiments show that measured depth could also be a function of material coating, as seen in Figures 1 and 2. In these Figures, a metal sample leads to different measurements whether its surface is painted or not. A characterisation of the measured depth as a function of the material will thus be conducted.

Secondly, corrections to measurement errors will be brought, as seen in Figures 3, 4, 5, 6 and 7. Simple algorithms such as median filters can be applied to get rid of noise due to dust in air and water - leading to diffusion mainly. Reduction of noise incurred by an oscillating water surface will also be considered. Then, routines will be found to overcome the problem of calibration of the Kinect. In fact, it was calibrated for being used in air, and the propagation of the NIR signals used by the depth sensor is significantly different whether in air or in water[1]. Refraction will also be taken into account.

5 Conclusion

There is still a lot to be discovered in using a Kinect sensor for underwater depth screening. The final goal -monitoring a dike failure- could only be achieved if the sensor is perfectly known. The behaviour of its measurements with respect to the materials used for building the experimental dike model must also be perfectly known. Because the sensor is not sold for underwater screening, algorithms must be developed to get rid of any problem due to noise, reflection, refraction and TOF theory.

[1] See Appendix to know about a simple algorithm to correct the measured depth.

6 Appendix

6.a Simple algorithm using Time-Of-Flight(TOF) theory

The Kinect V2 sensor is based on Time-Of-Flight calculation. A Near-Infrared-Signal(NIR) is sent from the sensor. The time taken by the signal to come back to the sensor is evaluated and the depth is[1]:

$$d_{\text{pixel}} = t_{\text{pixel}} \cdot c_{\text{air}}, \tag{1}$$

where d_{pixel} is the depth measured by the Kinect sensor. Eq. 1 is based on the hypothesis that the signal only travels through air, with a phase velocity c_{air}. The depth we want to measure is composed of two media: air and water. Knowing t_{air}, i.e. the time taken by the signal to travel through the air part of its path, one can get a correction for the measured depth:

$$\begin{aligned} t_{\text{pixel}} &= \frac{d_{\text{pixel}}}{c_{\text{air}}},\ t_{\text{air}} = \frac{d_{\text{air}}}{c_{\text{air}}}, t_{\text{water}} = t_{\text{pixel}} - t_{\text{air}}, \\ d_{\text{corrected}} &= t_{\text{water}} \cdot c_{\text{water}}, \\ d_{\text{pixel, new}} &= d_{\text{corrected}} + d_{\text{air}}, \end{aligned} \tag{2}$$

where $d_{\text{pixel, new}}$ is the corrected measured depth. Obviously, this simple correction requires the knowledge of the distance traveled by the signal through air, that is, the distance from the Kinect V2 to the water surface. As this will not be known, an alternative calculation should be found. For example, if there is a point in the dike model that does not *move*[2], the distance between this point and the Kinect sensor can be given to the algorithm before the experiment. The value of d_{air} can therefore be extracted from the following:

$$d_{\text{air}} \left(1 - \frac{c_{\text{water}}}{c_{\text{air}}}\right) = d_{\text{pixel, new}} - \frac{d_{\text{pixel}}}{c_{\text{air}}} c_{\text{water}}, \tag{3}$$

where one uses the true distance between the Kinect sensor and the fixed point for $d_{\text{pixel, new}}$. The value of d_{air} being known, it can be used around the fixed point as a first approximation to find $d_{\text{pixel, new}}$ at other points.

As seen in figures 3, 4, 5, 6, 7, the algorithm decreases the measurement error, but does not make it vanish.

6.b Figures

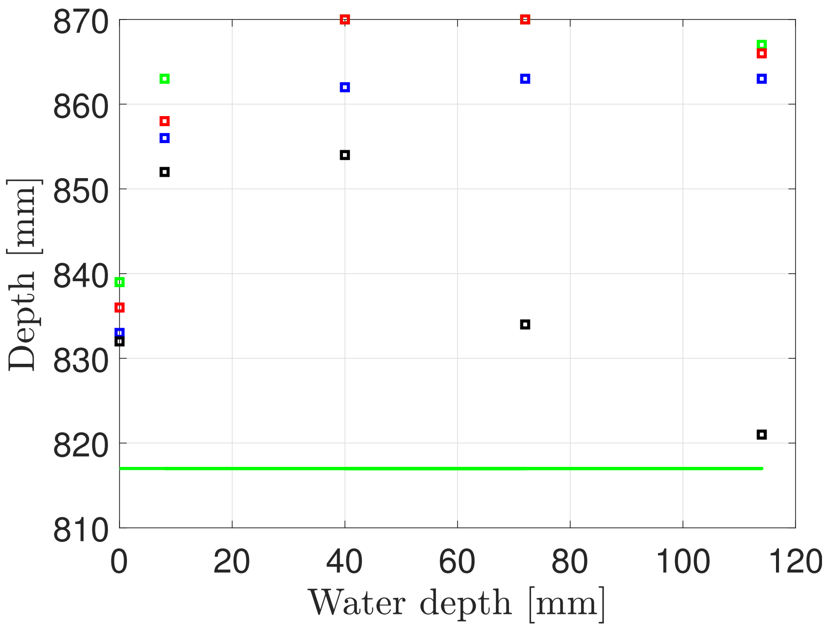

Figure 1: Measured depth by the Kinect sensor at 4 points of a painted metal sample (each of them having a specific colour). The sample is placed beneath the Kinect sensor, to avoid the influence of radial distortion.

[2]Points that move are for example sand parts of the model.

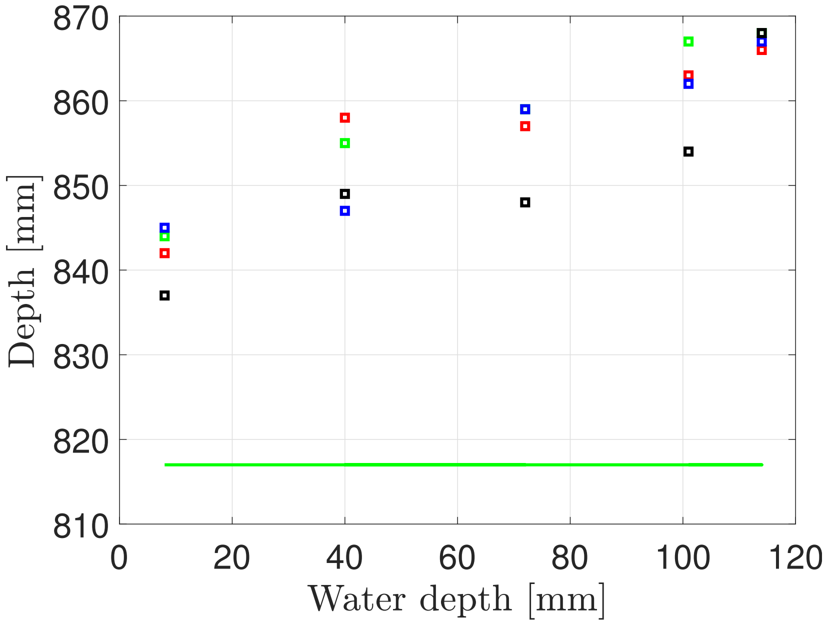

Figure 2: Measured depth by the Kinect sensor at the same 4 points as for Figure 1, on a non-painted metal sample. The sample is placed beneath the Kinect sensor, to avoid the influence of radial distortion.

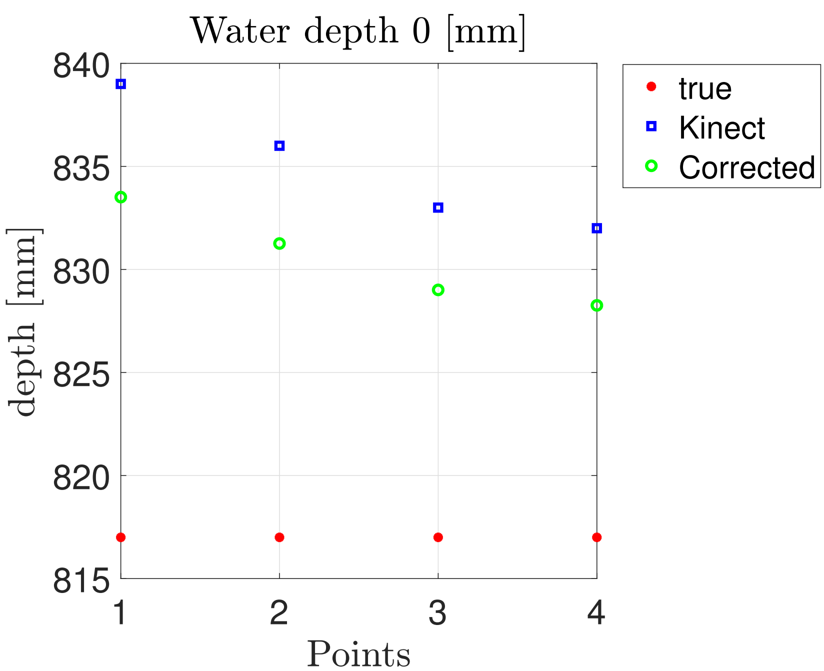

Figure 3: Measured depth at the 4 aforementioned points (denoted by *Kinect* in the legend). The water depth denotes the level of water above the sample. True depth is in red. Corrected depth using the simple algorithm described in subsection 6.a.

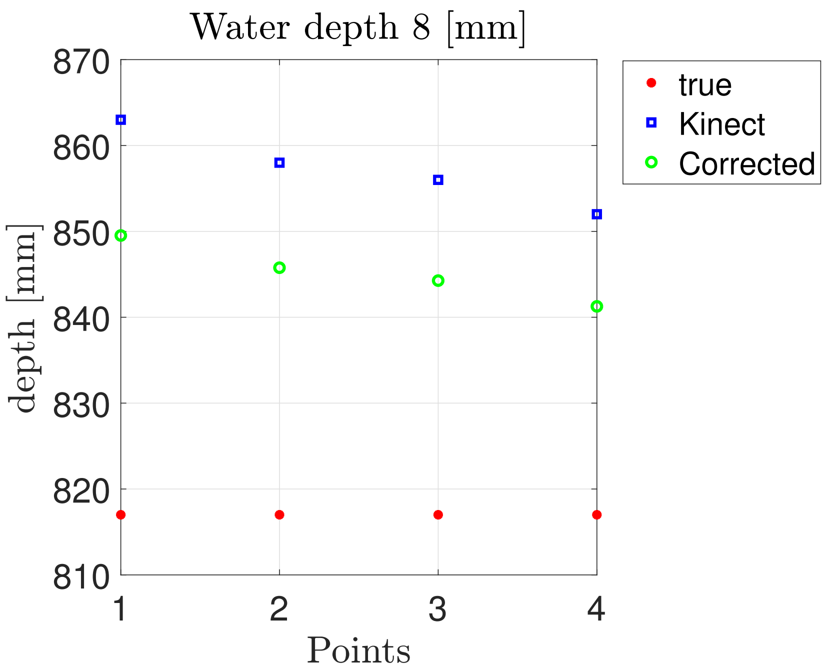

Figure 4: Measured depth at the 4 aforementioned points (denoted by *Kinect* in the legend). The water depth denotes the level of water above the sample. True depth is in red. Corrected depth using the simple algorithm described in subsection 6.a.

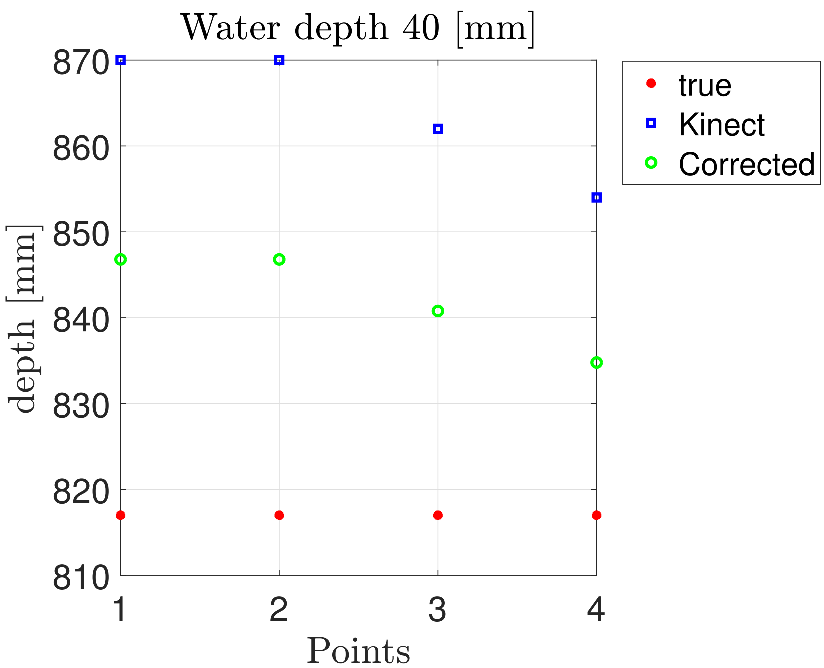

Figure 5: Measured depth at the 4 aforementioned points (denoted by *Kinect* in the legend). The water depth denotes the level of water above the sample. True depth is in red. Corrected depth using the simple algorithm described in subsection 6.a.

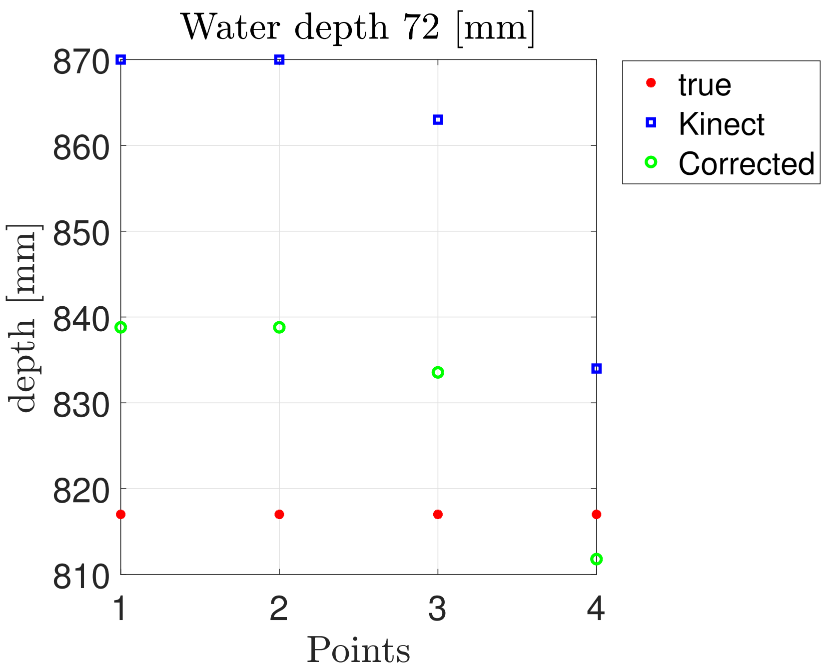

Figure 6: Measured depth at the 4 aforementioned points (denoted by *Kinect* in the legend). The water depth denotes the level of water above the sample. True depth is in red. Corrected depth using the simple algorithm described in subsection 6.a.

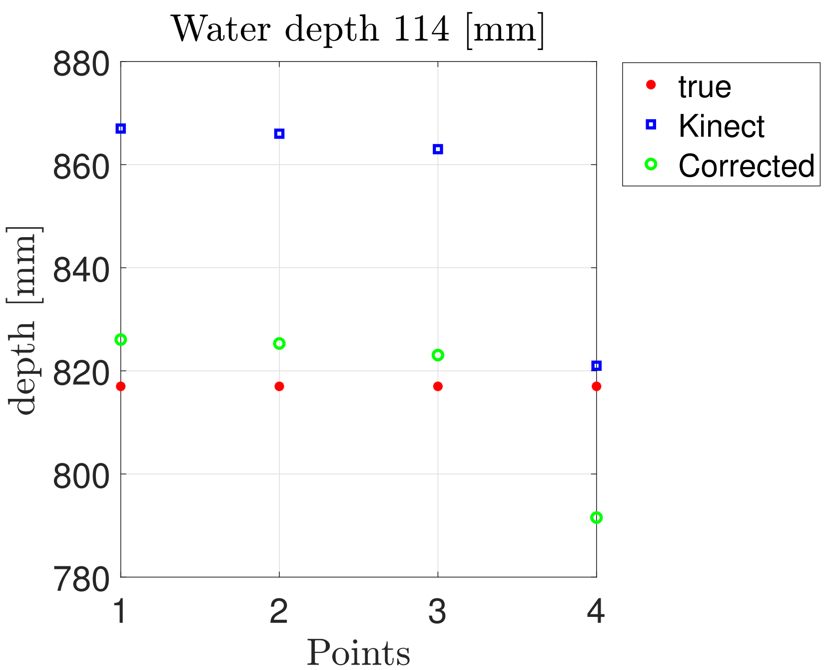

Figure 7: Measured depth at the 4 aforementioned points (denoted by *Kinect* in the legend). The water depth denotes the level of water above the sample. True depth is in red. Corrected depth using the simple algorithm described in subsection 6.a.

References

[1] ANWER ATIF et al. “Underwater 3-D Scene Reconstruction Using Kinect V2 Based on Physical Models for Refraction and Time of Flight Correction”. In: *IEEE* (2017). DOI: 10.1109/ACCESS.2017.2733003.