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Using LUT approach for deriving bathymetry can lead to sensitivity issues. If we have coarse depth spacing, we might loose accuracy and if the depths are too fine, we waste resources in generating LUT with more depths then needed, and the matching process is slower as it increases the number of entries to search. Having finer depths then required can also give misleading accuracy estimates to the user. Imagine a scenario where we have depths at one centimeter increments. If the reported depth is 40.24 meter, it might mislead the user into believing that the sensor can have centimeter accuracy at 40 meters, which might not be true. So an important consideration is to research the right number of depths in LUT for any n bit sensor with generic environment conditions.

A generalized version of the problem is, having a depth d_1 in LUT, we want to find a depth d_2, such that d_2 is as close to d_1 as possible and also that the hyper spectral signals for both the depths are different enough for a search algorithm to potentially be able to distinguish between them. The derived depths should be for a generic sensor and conditions so that it is applicable to all the sensors under different conditions. The approach taken was to generate a LUT with depth increments of 1 cm up to 50 meters for an environment with Pope and Fry pure water [1] and clear sand [2]. Having this LUT, we then try to extract adjacent depths that have enough difference in signal for a search algorithm to potentially distinguish between them. As pure water and clear sand makes the most ideal scenario for determining bathymetry, depths derived for such a scenario will be a comprehensive list usable for any real time environment. Thus we had an LUT with 5000 depths from 1 cm to 50 m for pure water and clear sand.

Different sensors have different resolution that can affect the optimum number of depths needed to generate bathymetry for data collected through that sensor. A n bit sensor can output 2^n discrete values. To avoid saturation, sensors are generally soft saturated at 80%. Thus the number of discrete values drops to $(0.8)\ 2^n$. The brightest signal that the sensor will receive will be of dry land. When there is even a thin layer of water, the observed signal drops down considerably due to refraction in water. We calculated the reflectance with just clear sand and with clear sand bottom with 1 cm of water. The ratio is both the reflectance is 0.75. Thus the brightest signal ever to reach the sensor from water will be 0.75 times the brightest signal of dry land. This results in number of discrete values useful to represent depths to $(0.75)(0.8)\ 2^n$.

A considerable part of signal observed by sensor is light reflected from atmosphere. Data collected through any sensor is typically run through atmospheric correction algorithms. The algorithms can eliminate as much at 90% of the signal from some bands. As our study is intended to encompass all scenarios, we keep the atmospheric reduction to very liberal amount of 60%. Thus we denote that 60% of the signal received will be removed as a part of atmospheric correction routines that the data goes through. As a result, the number of discrete values drops to $(0.40)(0.75)(0.80)\ 2^n = (0.24)\ 2^n$. Thus a signal will have any of $0.24\ 2^n$ discrete values and for a classification algorithm to be able to distinguish between two depths, the signal value of at least one band in the signal should be different. The only drawback of this approach is that the difference can very easily be from sensor noise and not actual depth difference. A very widely used signal to noise ratio (SNR) of 200 is used for the study. Again, a very liberal SNR is selected to maintain the generic aspect of the study. As the brightest water signal will be (0.24) 2^n, the SNR will be (0.005) (0.24) 2^n = (0.0012) 2^n. Thus, if any one of the signal bands of any given adjacent depths is different by the computed SNR for that sensor, an algorithm can potentially distinguish between them.

As noted above, we generated a LUT with 5000 depths, starting from 1 cm to up to 50 meters with 1 cm spacing. The LUT was then normalized and each signal value was converted to a discrete value. The brightest signal in the LUT was give the value of (0.24) 2^n as described above. The rest of the LUT signals were then scaled using their ratios to the brightest signal. Starting from the first depth entry in LUT, at 1 cm, the nearest depth from it, which had at least one band in the spectrum different by computed SNR was found and added to the list of required depths. This added depth then became the reference and the nearest distinguishable depth from this point was then found. Using this method for a 14 bit sensor, 292 depths were found that matched the criteria. The graphs provided below helps analyze the results.

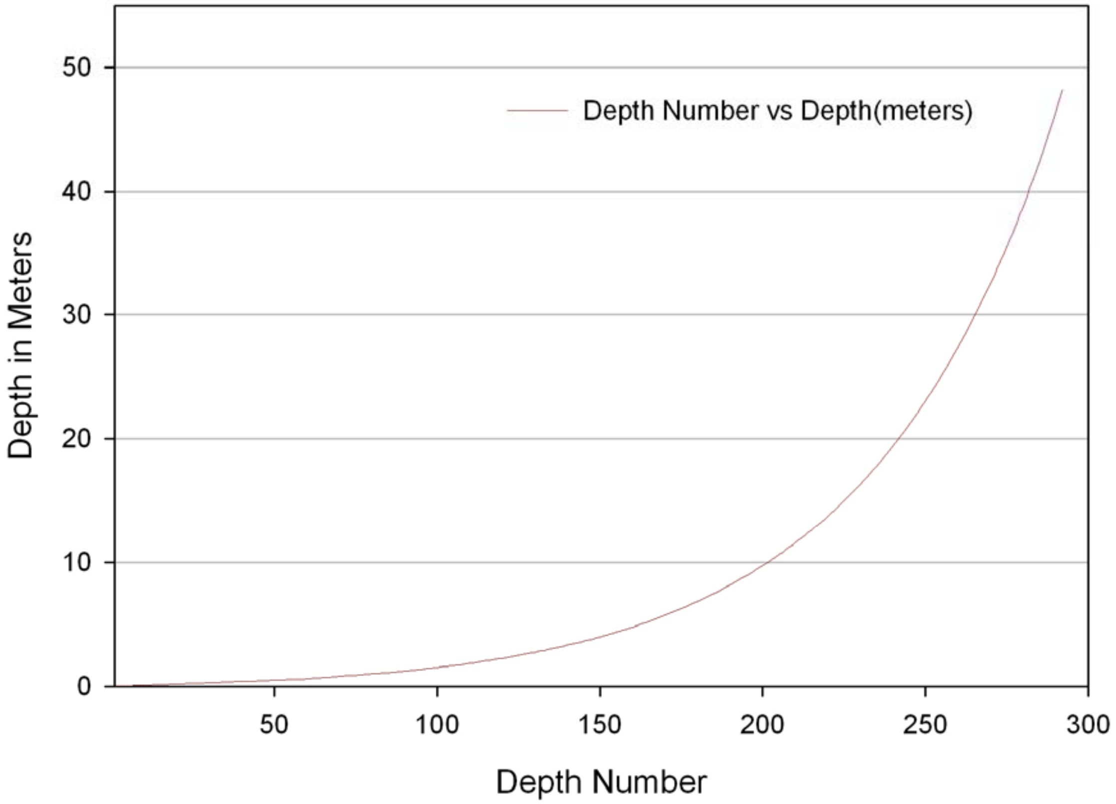

Figure 1: Graph plotting actual depth with depth number.

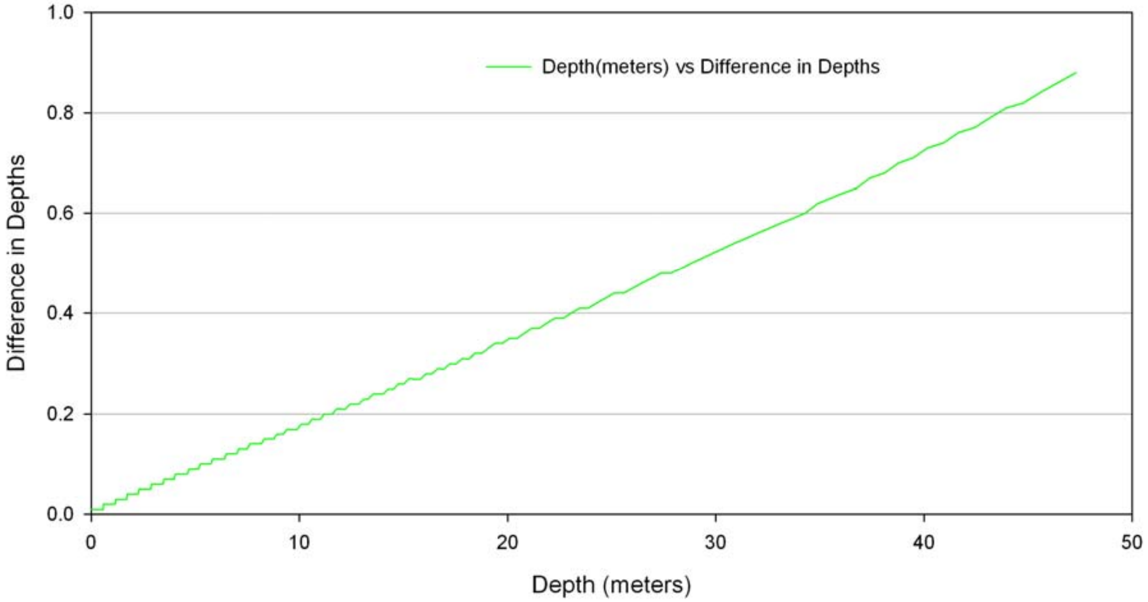

Figure 2: Graph plotting depth with difference between adjacent depths.

As shown in Figure 1 and Figure 2, as depth increases, the difference between adjacent depths also increases. With the increase in the depth, the hyper spectral signal observed weakens, and it becomes increasingly difficult to distinguish between two adjacent depths.

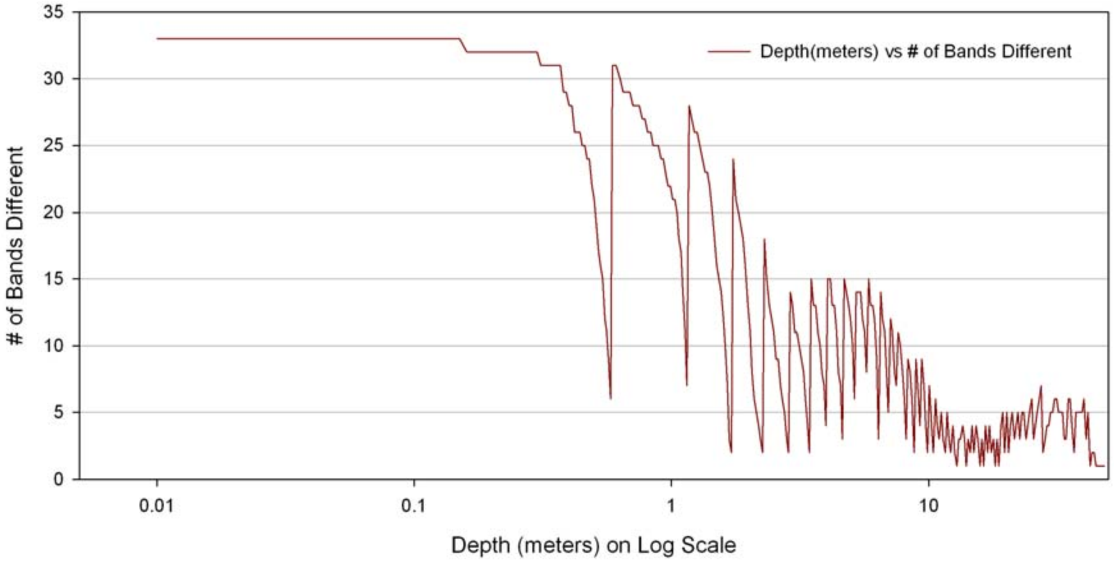

Figure 3: Graph plotting the number of bands by signal to noise ration for all the depths on a log scale.

As observed in Figure 3, the difference between the signals of adjacent depths reduces as the depth increases. For a certain depth discretization, the number of bands that are different reduces with depth, to the point where the two adjacent depths are not distinguishable, which induces increase in discretization which in turn results in a sharp increase in the number of bands different.

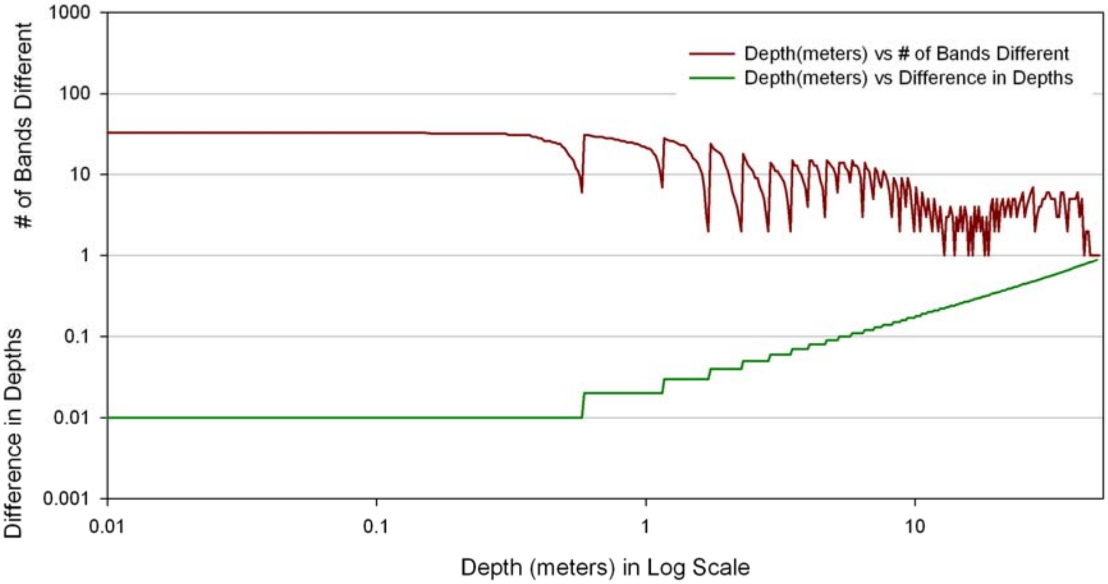

Figure 4: Different between adjacent depths and number of bands different plotted with depth.

Figure 4 confirms that whenever the discretization in depths increases, correspondingly there is a jump in the number of bands that are different.

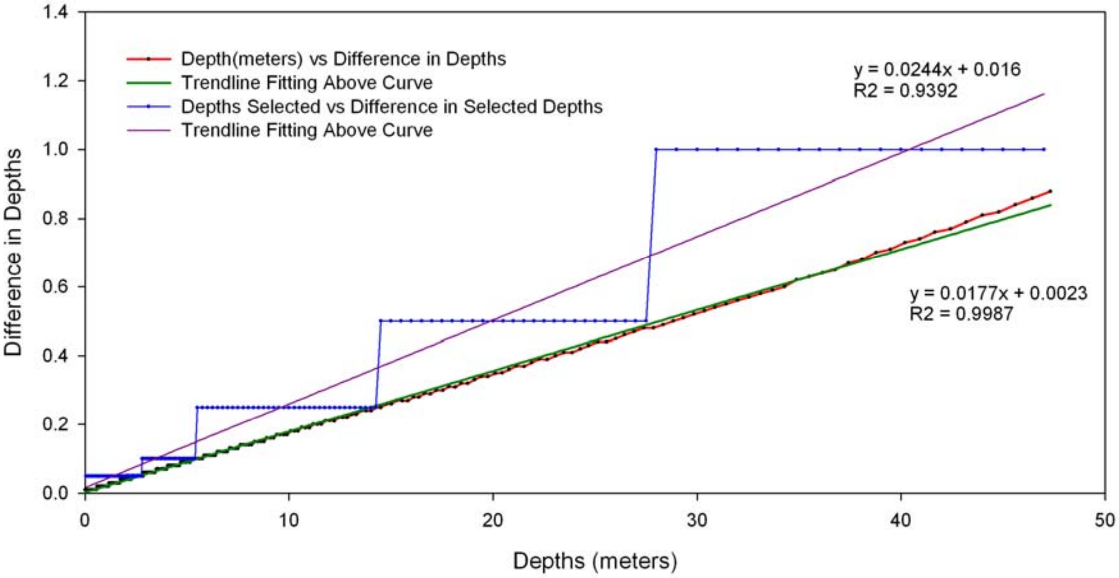

Figure 5: Depth discretizations and trendlines fitting them.

The red line in Figure 5 plots the difference in depths for all the depths selected. The green line is the trendline fitting that curve. Any depth discretization that falls below this line is too fine for that particular sensor to distinguish. Although, ideally we want all the depths selected to be on that trendline, it is practically not feasible to do so. Even though the sensor can resolve depths starting from 1 cm, it might not be needed for a particular application to have such fine depth discretization. For our application we chose to start from 5 cm. Also, by following that trendline, we might get depths that generate a false sense of accuracy. For example, the selected depths might have a depth of 39.74 meters and the next depth of 40.12 meters. If we report a depth of 40.12 meters for a particular point, it might induce the user to believe that we are able to resolve depths with a 1 cm accuracy even at 40 meters which is certainly not true. Thus rather then having a continuous discretization, a fixed discretization order must be selected that corresponds to the resolution of the sensor and also suites the application for which it is used. For our application we choose depths discretization of 5 cm, 10 cm, 25 cm, 50 cm, and 1 meter. The depths selected using these discretizations are plotted in blue color. The trend line fitting this curve is slightly above the trend line fitting the curve of depths with continuous discretization. This suggests that all the depths selected are distinguishable for this particular sensor; also they are not too far spaced to potentially loose accuracy.