ACCURACY OF AUTOMATED GRAIN SIZING (AGS) AT DIFFERENT GROUND SAMPLING DISTANCE

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ABSTRACT
Automated grain sizing technique (AGS) has been widely used to characterize the grain size distribution of particles at channel bed. Although a number of techniques were available as described in the literature, the accuracy of this technique was subject to further validation and verification. The accuracy of AGS technique is hindered due to over-segmentation and pixel resolution of the imaging samples. Another disadvantage / drawback is the distance between pixel centers measured on the ground. This paper discusses the grain size distribution (GSD) using AGS technique taken at different ground sampling distances. The GSD curve from AGS technique was fitted to the conventional curve obtained by sieving and correction factors were proposed to reduce errors between these two techniques. It was observed that different ground sampling distance did not affect the GSD. However, GSD using AGS and conventional sieving showed some variation due to over-segmentation. The use of correction factors gave better results and it was nearly unity between two techniques.

Keywords:
Automated Grain Sizing, Grain Size Distribution, Sieving, River Bed, Bed Material, Correction Factor

INTRODUCTION

Grain size analysis is a common test in geotechnical engineering to determine the relative proportions of the various particle sizes in a given soil sample in the laboratory or in the field. Generally, researchers or practitioners use mechanical sieving or pebble count to determine the grain size distribution (GSD). Although advanced laboratory equipment is being used in the technique it is still time consuming. Fluvial environment research often requires river bed material information for the purposes of obtaining roughness length-scale estimates, sediment transport calculations, geomorphic or aquatic habitat classification and general monitoring (Strom et al., 2010). Nowadays, the process can be expedited by using image-analysis to automatically extract grain-size information from digital images of soil samples at the river bed. Generally, AGS technique can be divided into two; either by extracting grain-size information from digital images of bed samples using the statistical properties of the total image grain texture (e.g: Rubin 2004; Barnard et al., 2007; Buscombe 2008; Buscombe and Masselink 2009) or by locating individual grain boundaries (McEwan et al., 2000; Butler et al., 2001; Sime and Ferguson 2003; Graham et al., 2005a; 2005b; Strom et al., 2010; Graham et al., 2012; Chang and Chung 2012; 2013; Sulaiman et al., 2014). The former assumed that grains within an image are not treated as an individual object, but as a group of textures (Buscombe and Masselink 2009) while the latter implies the use of edge detection and image segmentation principles (Sulaiman et al., 2014).

Critical Remarks

Although AGS technique provides ease to the researcher, the accuracy and reliability of AGS technique is subject to further verification (Sulaiman et al., 2014). There are many factors that hinder the accuracy of AGS technique; over-segmentation, pixel quality, tilting and pixel unit. Pixel unit and over-segmentation were given special attention in this paper and numbers of repetition were made (capturing the image) to elucidate the effect of these drawbacks to the accuracy of AGS technique. The results on GSD for AGS technique is fitted to the conventional mechanical sieving in order to observe the accuracy of AGS technique. GSD from the sieving method was taken as the true value since percentage frequency by weight alleviates the bias towards operator's error. Furthermore, sieving technique is a recommended method and widely used in the field of civil engineering. British Standard BS 1377-2: 1990 Section 9: "Determination of particle size distribution" clearly depicts the use of opening size of sieving pan which is similarly the same with the Wentworth scale. The sieve size (d_s), typically advance of a logarithmic series based on 2 (Bunte and Abt 2002) such that

$$d_s = 2^x \tag{1}$$

where x is usually the bin size in increment of 0.5. The pan size of 20 mm, 14 mm, 10 mm, 6.3 mm, 5 mm, 3.35 mm, 2 mm, 1.18 mm, 0.6 mm, 0.425 mm, 0.3 mm, 0.212 mm, 0.15 mm, 0.063 mm and appropriate receiver were used in accordance with BS 1377-2 to obtain the actual GSD. The aims of this paper are: 1) to test the accuracy of AGS technique compared to conventional sieving; 2) to correct the AGS distribution curve by implementing correction factor.

AUTOMATED GRAIN SIZING TECHNIQUE (AGS)

The analysis of grain size distribution can be divided into two types of approach; mass-based technique and 'counting-based technique. In the mass-based technique the full use of sample weight and the fraction weight of the retaining mass on the sieve pan was considered. However, in the counting-based technique the percentage of frequency of the counted material as previously suggested by Wolman (1954) was calculated. The latter technique of AGS (locating individual grain boundaries) uses the counting-based technique where the intermediate axis of each identified particle are counted. Strom et al. (2010) postulated that imaging technique should encompass 4 major steps, namely 1) obtaining images; 2) image processing; 3) image analysis from available software; 4) obtaining GSD from image analysis. Step-by step application of AGS techniques is shown in Table 1.

Table 1: Execution steps of Automated Grain Sizing (AGS)

Step	Process	Theme	Software / Tool
1.	Image captures using a digital camera (inclusive of physical meter)	Obtaining image	Digital camera
2.	Cropping the preselected image	Image processing	Image J
3.	8-bit image conversion	Image processing	Image J

4.	Median filtering	Image processing	Image J
5.	Binary threshold	Image processing	Image J
6.	Morphological close and watershed	Image processing	Image J
7.	Measure grain; fit ellipse	Image analysis	Image J
8.	Numerical sieving	GSD	Built in program-Igor Pro

Figure 1 shows step-by step execution of AGS graphically using the public domain Image J and Igor Pro software. Previously, practitioners from medicine use the Image J software to count the number of nuclei in a substance and some astrophysicists use Image J to count the stars in the sky. The capability of Image J to identify the edge of an object is crucial as AGS technique acquire the detection of image boundary, thus automatically identify the boundary dimension. The resulting GSD emulates the use of an area-by-number distribution. Thus, it is not comparable to distributions obtained by sieve analysis (Sulaiman et al., 2014). Thus, GSD from AGS technique must be converted using the following equation.

$$n_{ai} = \chi n_i \tag{2}$$

where n_{ai} is the adjusted number of grains in size fraction i after transformation, n_i is the original number of grains in size fraction i, and χ is a transformation function:

$$\chi = e^{\beta' \overline{\psi_i}} \tag{3}$$

where $\overline{\Psi_i} = (\Psi_i + \Psi_{i+1})/2$ is the mean size in psi units of size fraction i, and $\beta' = \beta ln2$ with β being the transformation coefficient. Using Kellerhals and Bray (1971) (see Table 2), the conversion from area-by-number to a volume-by-weight distribution (sieving) can be obtained by letting $\beta = 2$. This conversion assumes that the cube model is appropriate and that the sieve aperture sizes correspond to the intermediate axis of the measured particles (Sulaiman et al., 2014).

Table 2: Conversion Factor for Particle Size Distribution

Conversion from	Conversion to				
	Volume-by weight	Grid-by number	Grid-by weight	Area-by number	Area-by weight
Volume-by weight	1 0	1 0	D^3 3	$1/D^2$ -2	D 1
Grid-by number	1 0	1 0	D^3 3	$1/D^2$ -2	D 1
Grid-by weight	$1/D^3$ -3	$1/D^3$ -3	1 0	$1/D^5$ -5	$1/D^2$ -2
Area-by number	D^2 2	D^2 2	D^5 5	1 0	D^3 3
Area-by weight	$1/D$ -1	$1/D$ -1	D^2 2	$1/D^3$ -3	1 0

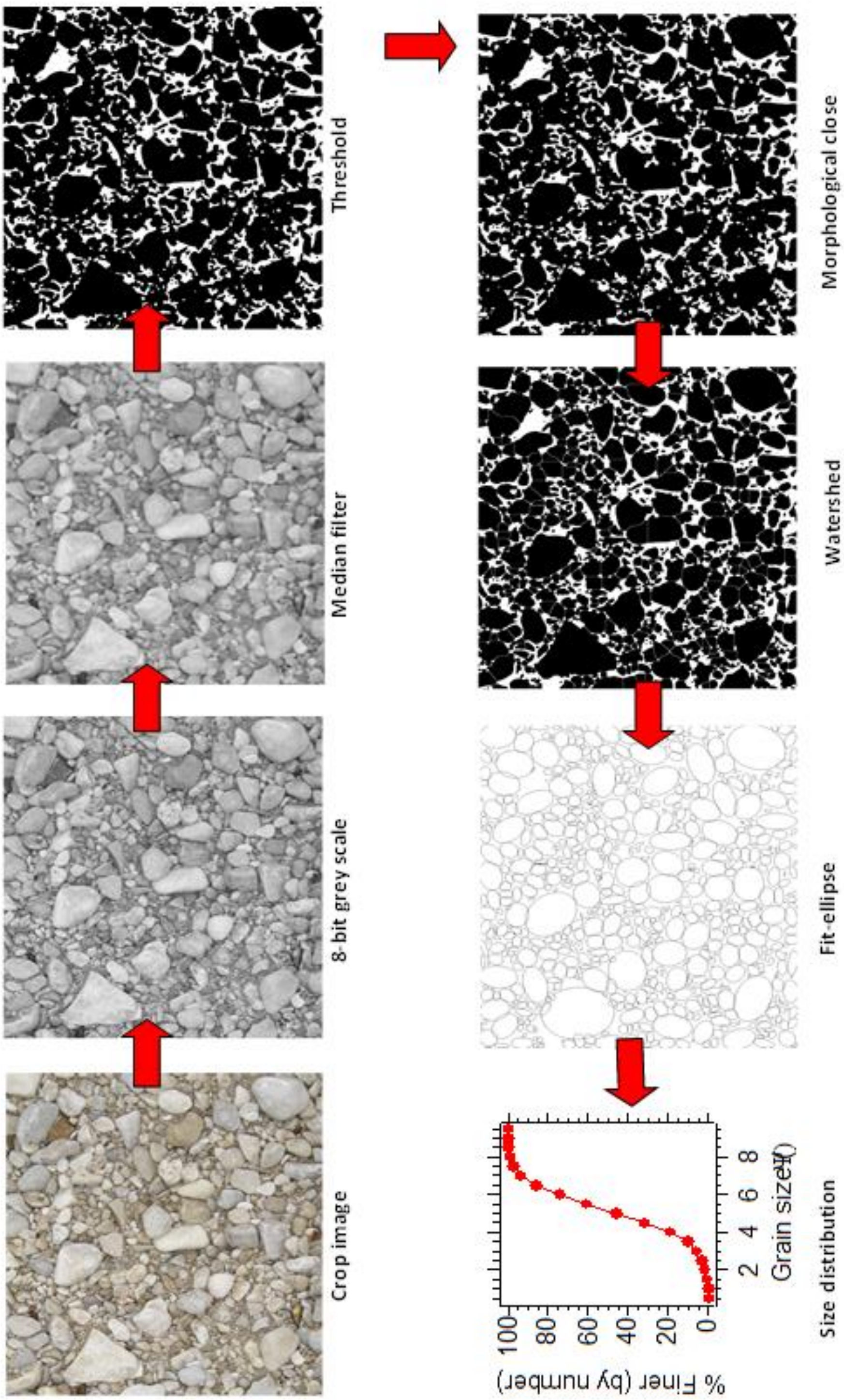


Figure 1: Basic principle of image processing technique

METHODS

The One-to-one plot for GSD by Automated Grain Sizing (AGS) has been found to show the accuracy of the technique as opposed to widely using mechanical sieving. Prior to the development of the GSD, few samples were collected at Sungai Inki, Selangor (see Figure 3), to represent the whole river transect. The samples were taken at 6 different locations from the river transect namely Downstream Left, Downstream Middle, Downstream Right, Upstream Left, Upstream Middle, and Upstream Right. The distances between the upstream and downstream are roughly 100m. Six samples of dates were grabbed to illustrate the variation of GSD across the transect.

Figure 2: Distribution of samples at Sungai Inki, Selangor

The samples were brought to the laboratory for drying at 104 (C for 24 hours, the samples were spread on aluminium trays placed on a level ground and images were captured at a different ground sample distance in the vertical direction (see Figure 3). A meter ruler was placed on the tray to capture the physical scale of image. The digital camera axis were maintained perpendicular to the tray plane to avoid inclination. At each point, the image was taken at 3 different distances in the vertical direction between the camera lens and the sample area, i.e. 2cm, 5cm, and 7 cm (see Figure 4). Each area produced 3 images and each image was processed accordingly.

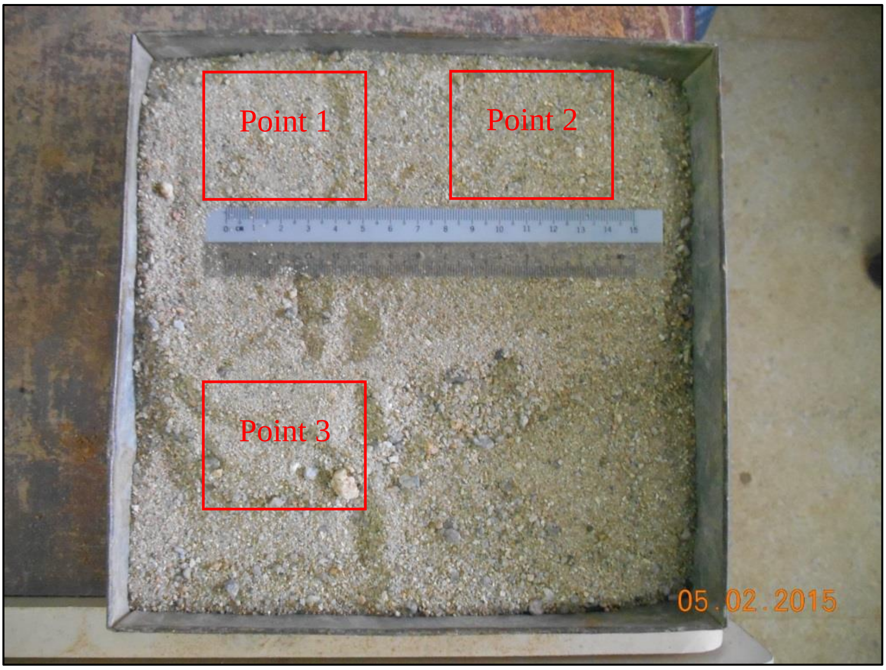
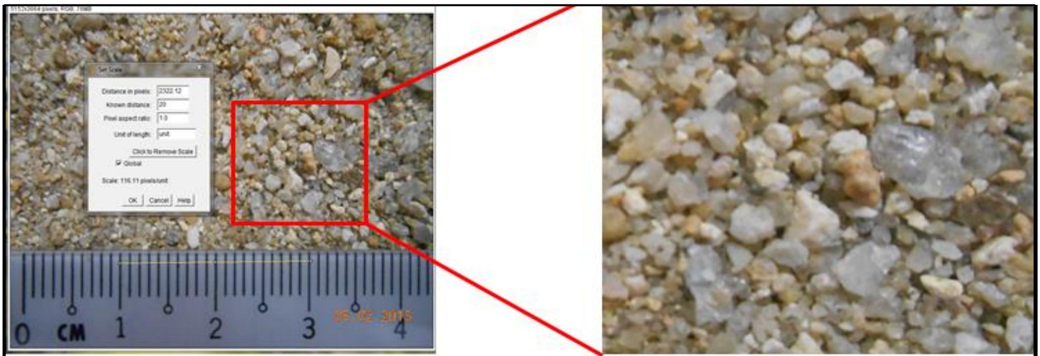


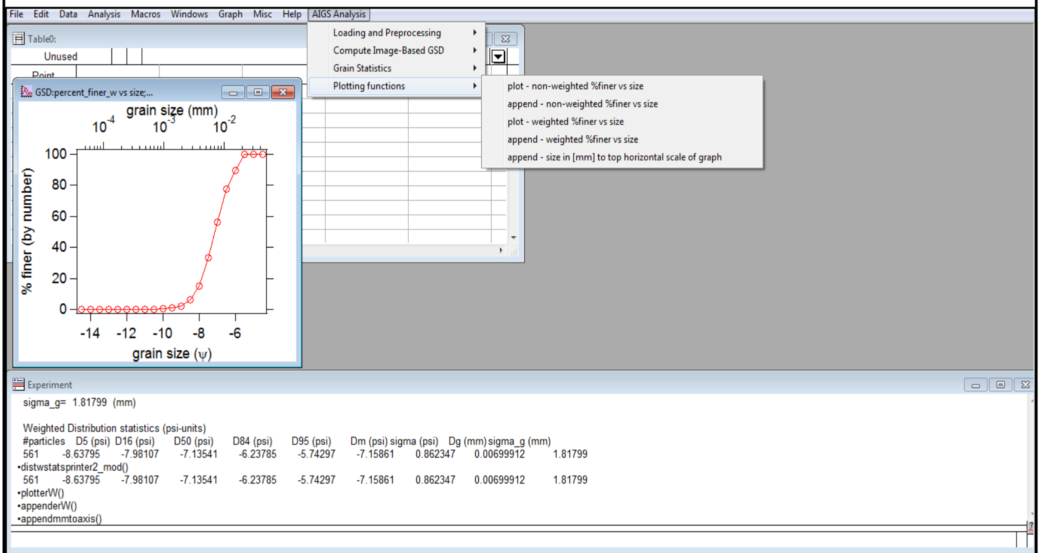
Figure 3: Areal photo of samples

Figure 4: Distance between camera lens and sample

Image J software is used for image processing technique and extracting grain information while the built-in Image J software is used for numerical sieving and creating grain size plot (Figure 5).



a) Image J processing



b) Built-in Igor Pro

Figure 5: Software Modelling and analysis tools

The root mean square error method and also standard deviation will be applied to check the error of GSD graph plotted between AGS and mechanical sieving. The root mean square error or also known as the average of the square of all of the errors can be calculated by (Amaral 2014):

$$RMSE = \sqrt{\frac{\sum (AGS - Conventional)^2}{n}} \tag{4}$$

where *n* is the number of sample data.

RESULTS AND DISCUSSION

The percentage distribution of soil particles from manual sieving and AGS techniques were compared to observe the discrepancy between these two techniques. However, AGS technique is plotted for three different ground sample distance, namely 2 cm, 5cm and 7 cm. These 4 plots of GSD are shown in Figure 6.

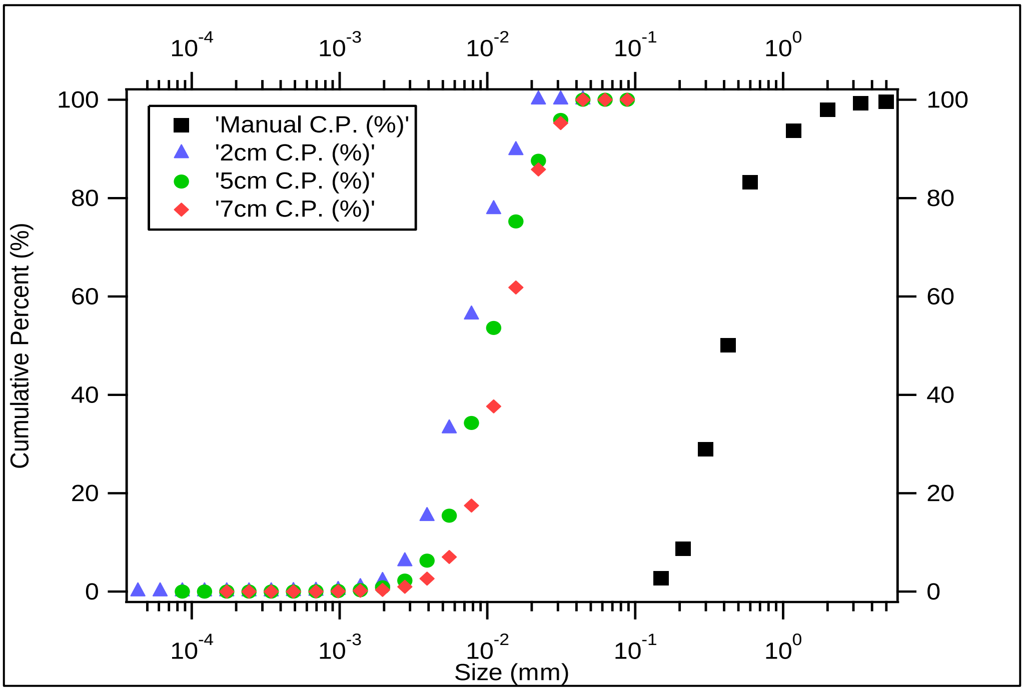


Figure 6: Grain Size Distribution (GSD) for Different Techniques

It can be observed that the discrepancy between different ground sample distances is small. However, AGS technique and mechanical sieving pose a large discrepancy between them. These differences can be perused in Table 3 where standard deviation and root mean square error (RMS) between imaging and mechanical sieving is quite large (>1). Thus, a simple empirical correction factor is introduced to correct these discrepancies so that the RMS and standard deviation is close to 0.

Table 3: Calculated Standard Deviation and RMSE for Downstream Left Point 1

	Manual / AGS			**AGS / AGS**		
	Manual: 2cm	Manual: 5cm	Manual: 7cm	2cm : 5cm	2cm : 7cm	5cm : 7cm
Standard Deviation	9.59	6.26	5.94	0.03	0.04	0.10
Root Mean Square Error	7.93	6.51	5.99	0.82	0.75	0.92

The least square method was employed to find the empirical correction equation for different ground sample distance. The sample of least square technique for ground sample 2 cm is shown below.

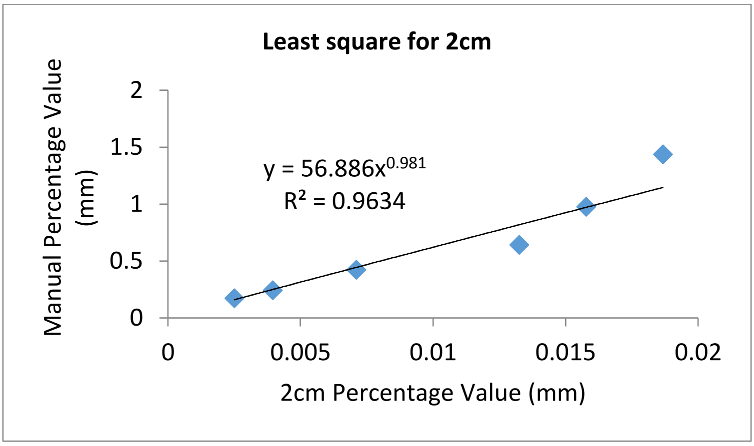


Figure 7: Least Square Technique for Ground Sample 2 cm

Different ground sample distance will have a different correction factor as shown in equation 5-7.

$$y = 56.886x^{0.981} \quad (5)$$

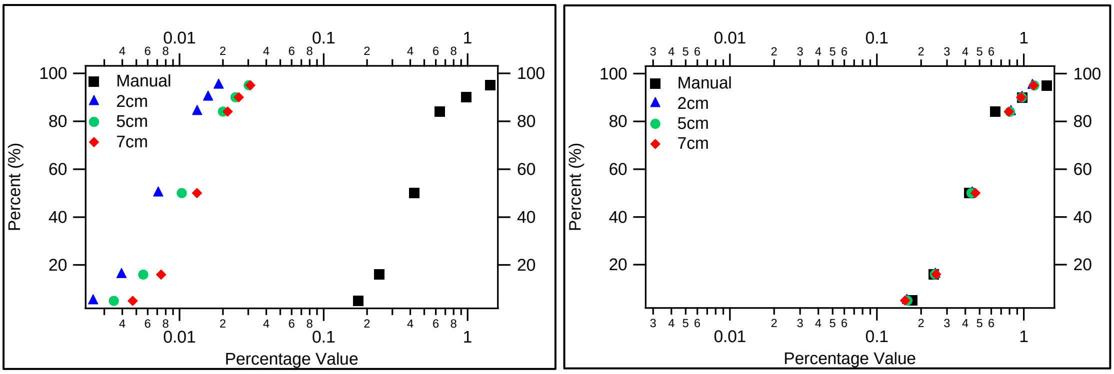
$$y = 29.836x^{0.923} \quad (6)$$

$$y = 47.9866x^{1.07} \quad (7)$$

where y=after corrected value and x=before corrected value. Deploying these empirical correction formulations to AGS technique improved the GSD significantly as the standard deviation close to 1 and RMS close to zero.

Table 4: Improvement after Employing Correction Function

	Before		After	
	Standard Deviation	Root Mean Square Error	Standard Deviation	Root Mean Square Error
Manual: 2cm	9.59	7.93	0.40	0.79
Manual: 5cm	6.261	6.50	0.15	1.00
Manual: 6cm	5.944	5.99	0.41	0.79
2cm : 5cm	0.038	0.82	0.13	1.00
2cm : 7cm	0.04	0.75	0.40	0.79
2cm : 5cm	0.11	0.92	0.15	1.00



a) Before Correction b) After Correction

Figure 8: Improvement of GSD after Correction

CONCLUSIONS

An experimental investigation on the use of AGS for grain size distribution of material at a river bed has been performed. Various correction factors at various particle sizes were applied to the curves thus obtained and it was found that the method was comparable to the conventional mechanical sieving. From the preceding section the following conclusions were made;

i) Obtaining the sample image at a different sampling distance will not give significant difference on the GSD curve should AGS technique is used for analysis.
ii) GSD curve and AGS curve showed a significant discrepancy between them.
iii) A correction factor should be employed to correct those discrepancies and the ratio between them is almost close to unity.

There are a few factors that could influence the result of AGS to become inaccurate. The error could be caused by: the quality of the capturing the image; blurring due to shaky hand when taking the images; too much noise in the picture which caused by the lighting and over-segmentation by the imaging software. It is suggested that the camera be mounted on a rigid frame to avoid man made errors. The correction functions produced by the least square method are capable to correct those discrepancies. A single and uniform correction factor is very much helpful and practical to be developed and used in the future.

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