Landslide Monitoring by Photogrammetry in Mongset Area, Northwestern Vietnam

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Abstract

Stereo-photogrammetry techniques have been applied for monitoring landslide conditions in the MongSet area, northwestern Vietnam during 2002 to 2003. This technique afforded surface deformation mapping of the landslide with a high spatial resolution and accuracy. Photomodeler software was used for this purpose. Photographs taken with an ordinary digital camera were analyzed using reference points. The technique applied has helped to estimate the movement of the landslide for one year. The promising results were validated by comparing independent measurements carried out by a laser telemeter that thus established the validity of the technique.

1. Introduction

Recent advances in survey technology have facilitated reliable and increasingly accurate measurement and analyses of various geographical feature data. Among the remarkable advances in this field are those related to photogrammetry and GPS techniques where the accuracy of measurement is quite high. These techniques play key roles in many environmental applications such as landslide monitoring. Several methods for landslide monitoring now exist. Such methods can be divided into two groups: (1) methods for investigating change of geographical features, and (2) methods of investigating the motion in the ground. Installing a device such as an inclinometer on the moving land units can help greatly in estimating any movements which may occur. Other than using incinometers, monitoring of landslides is mainly determined using GPS (Paolo et al., 2003 etc.) and extensometers, and by the amount of change of reference geographical features using SAR-interferometry (Dario et al., 2003) etc. This method is effective to know change of the landslide landform, but it is not suitable for calculating the exact amount of movements of the landslide because of this data describes the landform of the landslide, rather than precisely determining movement vectors. In order to calculate the exact amount of movements of the landslide, it is necessary to develop a suitible method.

In this research, we used the stereo-photogrammetry technique using Photomodeler software (Eos System Inc, 2000) and a common digital camera, in order to calculate the exact amount of movements of the landslide. This technique was performed twice in the MongSet area, in the northwestern Vietnam in 23-24/DEC/2002 and 13-14/DEC/2003. We estimated the exact amount of movements of the landslide for one year from the result. Similarly, we performed the geological survey in this area. Those two results are introduced in this paper. This research is planed through the activity of the Japan-

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Vietnam Geoinformatics Consortium (JVGC) and the first case of the field joint research supported by JVGC. Another purpose of this research is the inspection of the landslide area in the northern part of the Vietnam and the setting for the joint research field on the landslide disaster.

2. Topographical and Geological Setting

The main route (Road No.4) from LaoCai to SaPa traverses the straight valley of the Ngai Dum River in the direction of NE-SW. Along this route, Proterozoic and Cambrian Systems are widely distributed (Figure 1).

The lower mountain area (altitude less than 500 m) which is located from Lao Cai to the southwest side of LaoCai, mainly consists of Cambrian schist including sandy schist and marble. The Cambrian system exhibits remarkable schistosity and faults trending in a NW-SE direction, forming mountain ridges trending in a NW-SE direction. The MongSet landslide area (altitude form 700-900 m) mainly consists of Proterozoic granitic rocks (the Po Sen complex; Geological Survey Inter-Group, 1978). The main lithology of these granitic rocks is sheared hornblende biotite granodiorite. The main shear foliations in these rocks are formed by right lateral displacements NNW-SSE direction along the regional geological structure affected by the Red River Fault. The weak foliations observable in the granite of the Mong-Set area dip to the east. The main joint system is formed along these foliations. Sheeting joints dipping to the valley are formed in the upper part of the weathered granite. On the lower part of the mountain slope (altitude from 500 to 1000 m), a very thick weathered zone (from 50 to 100 m thick) is generally distributed. The foliation structure is remains observable in these weathered soils. Debris flow deposits including boulder gravels with muddy matrix are distributed in the small branch valleys.

The MongSet Bridge is located at the mid-point of the LaoCai - SaPa route (Figure 2). Several landslides occur in this area. We tried topographical survey at the landslide site adjacent the Road No. 4. This landslide is 100 - 200 meters wide and is located at the southern slope, dipping 20 - 35 degrees. Road No. 4 is traverses the foot of the landslide. A gravity retaining

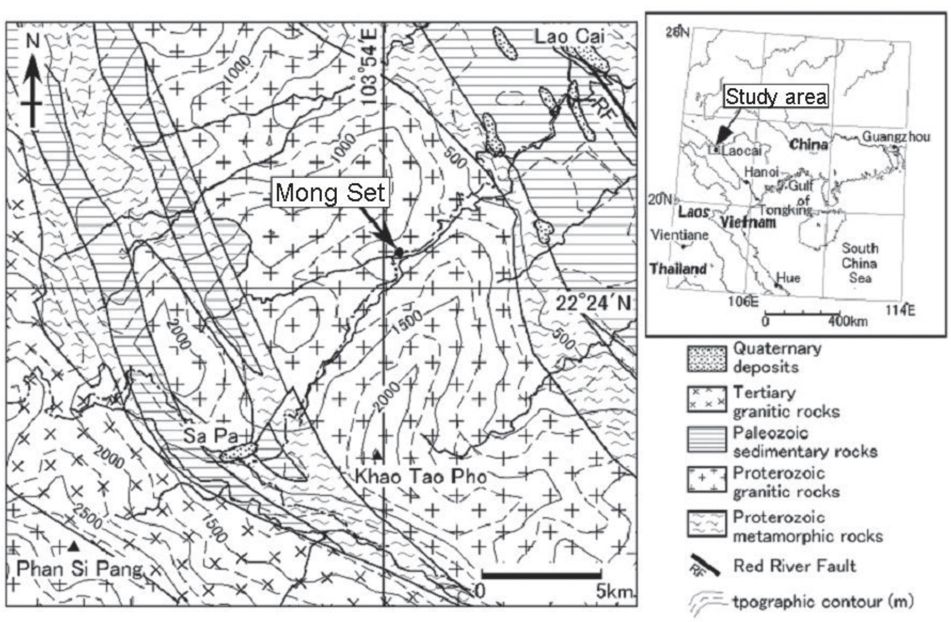

Figure 1: Geological map of Lao Cai and SaPa area
(Modified from Geological Survey Inter-Group, 1978)

wall and surface water drainage were constructed for slope protection. However, the surface water drainage has been broken by slope movement. Figure 3 shows landforms in this site.

3. About the System

The main equipment for performing monitoring, which we used, is as follows.

(1) *Digital camera; Canon PowerShot G3*
Digital camera Power shot G3 can take photographic images which of about 4 Mega pixels (2272 × 1704), and can save images in JPEG and RAW format.

(2) *Laser telemeter; Leica TPS307JP*
Laser telemeter Leica TPS307JP can measure to about 1000m at the maximum using prism. The measurement accuracy of this machine is 2 mm + 2 ppm of measurement distance.

(3) *The photogrammetry software; Eos Systems Inc. Photomodeler Pro 4.0*
The photogrammetry software Photomodeler Pro 4.0 is a Windows program, which can derive 3D models from stereo-photography. After making a 3D model, we can measure using it. The software can input common image file formats of JPEG, BMP, TIFF, etc. and can output 3D model formats of XML, DXF, etc.

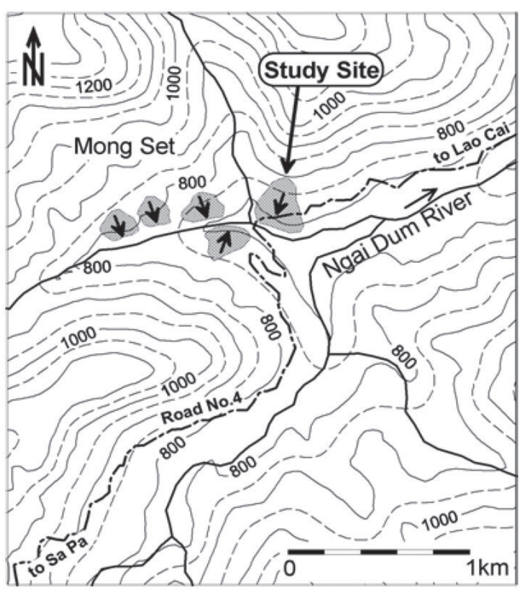

Figure 2: Topographical map adjacent the Mong Set landslide area (Modified from Department of Survey and Mapping, Vietnam, 1978)

4. Materials and Methods

4.1 Materials

(1) *Reference point*
We selected reference points, needed for the stereo-photogrammetry on 23-24/DEC/2002, shown as A1-A4 in Figure 3. P0-5 in Figure 3 are the reference points for the laser telemeter. In order to estimate the amount of movements for one year, we resurveyed the area one year later, on 13-14/DEC/2003. It is the point of P0-5 that the difference between the two years could be seen, as shown in Table 1. System of coordinates is X-axis in the direction of north and is the Y-axis in the direction of the east and P0 is starting point (0,0,0).

(2) *Photograph*
We took photographs for creating three-dimensional models after a survey by laser telemeter. As for the stereo-photogrammetry using a aerial stereo photographs, in many cases, photographs are taken in parallel. However, photomodeler can also make three-dimensional models with non-parallel stereo-photography.

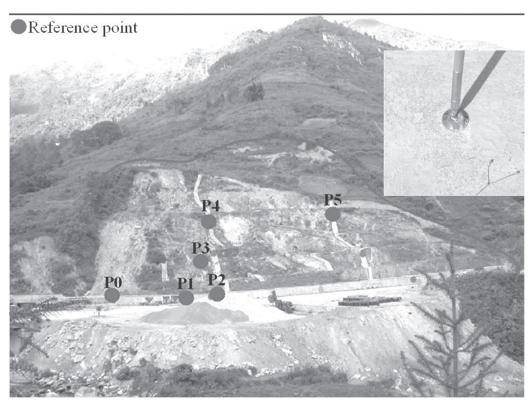

Figure 3: Landform of MongSet landslide area and the distribution of reference points

4.2 Methods

The method utilizes stereo-photogrammetry and Photomodeler Pro 4.0. Photogrammetry is the technology of searching for physical quantity and character of photographic subjects reflected in a photograph. Physical quantity shows the position of three-dimensional space, such as a location, a length and a square of photographic subject reflected in the photograph. This research, though not using the aerial photograph, photographs taken on the ground are primarily used to calculate physical quantity.

Photogrammetry is a technology which involves the acquisition of information about a form of photographic subject from the geometric relation between the images, and photographic subjects, which were projected on the surface of the film or CCD. The collinear conditions that there are three points of photographic subject, lens center and film or CCD surface on the same straight line are used. However, it is impossible to acquire three-dimensional information of photographic subject from one photograph, unless special conditions are given. Generally, the stereo model is created from a set of two-sheet photographs taken from two known positions. After creating the stereo model, we can measure three-dimensional information. Figure 4 shows the principle, by which depth of photographic subject is measured using stereo photography. Generally in stereo-photogrammetry, parallel photography (Figure 5(a)) which takes the photograph in parallel is used. In addition to this form, other methods of stereo photographs, such as convergent photographing (Figure 5(b)), exists. Photomodeler software can be used for these photographic methods. The reference points and stereo-photographs can be input, and a stereo model can be created with the software. After creating the stereo-model, we can determine 3-dimensional positional information. Further, the accuracy of those analyses can also be determined. The method for monitoring the landslide using Photomodeler is as follows.

The process first involves determining the position of each photographic element from the positions of the reference points. Then, we can determine the coordinate values of specific locations chosen within both of the photographs. Photomodeler can do this work easily. The method of carrying out monitoring using the data of two different times is as follows.

(1) The database for each survey time in Photomodeler, is created and photograph position is decided by analysis.
(2) The reference points are identified from the database of the two different times, and the values of each location is calculated.
(3) By determining the relative differences of each point, the amount of movement for each point over one year can be computed .

Figure 6 is the database created using the reference points and photograph for the stereo-photogrammetry. Every point in Figure 6 is used in order to determine position.

5. Results

Table 2, Figure 7 and Figure 8 are the result of the analysis obtained by the stereo photogrammetry. In Table 2, the given numbers are

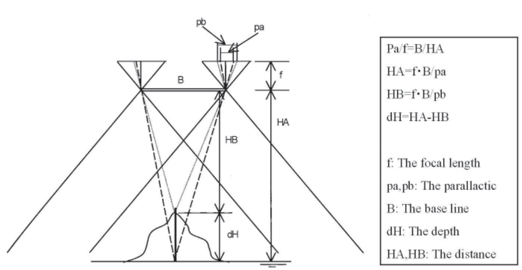

Figure 4: The principle measures depth of photographic subject (Muraki et al., 2002)

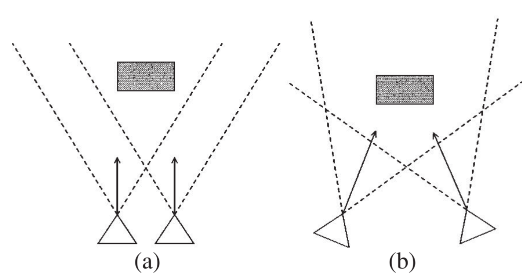

Figure 5: Photographing method (Muraki et al., 2002)

the coordinates of the respective points, as shown in Figure 9. The first lines are the data (x,y,z) in 2002, the second lines are the data in 2003 and the third lines are the differentials. Figure 7 shows how much each point (Triangle point) moved based on the data of 2002. Each point (Circle point) in Figure 7 is the result of measuring using laser telemeter. The arrow in each point shows the direction of movement of that point. Further, the dashed line is a contour line describing conditions in 2002 and Solid lines show a contours for 2003. Measuring many points in each stereo model using Photomodeler created these contour lines. This contour interval is 1 m. The line in Figure 8 shows the amount of feature change.

From these figures and Table 1 and Table 2, we can say that the each point, measured by the stereo-photogrammetry, is almost the same as the data measured by the laser telemeter. In Figure 7 and Figure 8, the place enclosed with circle can see that the amount of movements is large.

6. Conclusions

In this study, we monitored the landslide in the MongSet area, northern Vietnam, using a common digital camera and three-dimensional-analysis using Photomodeler software. The results were verified by laser telemeter.

We found that this method was effective. When performing monitoring using this method, work other than photography is done in the laboratory. Therefore such other work is not affected by weather. As there is no necessity to measure all points in the field, it is possible to shorten the time of actual field work. Further, though an initial purchase investment of software, a camera, etc., is required, investigating relatively cheaply after that is possible.

Acknowledgements

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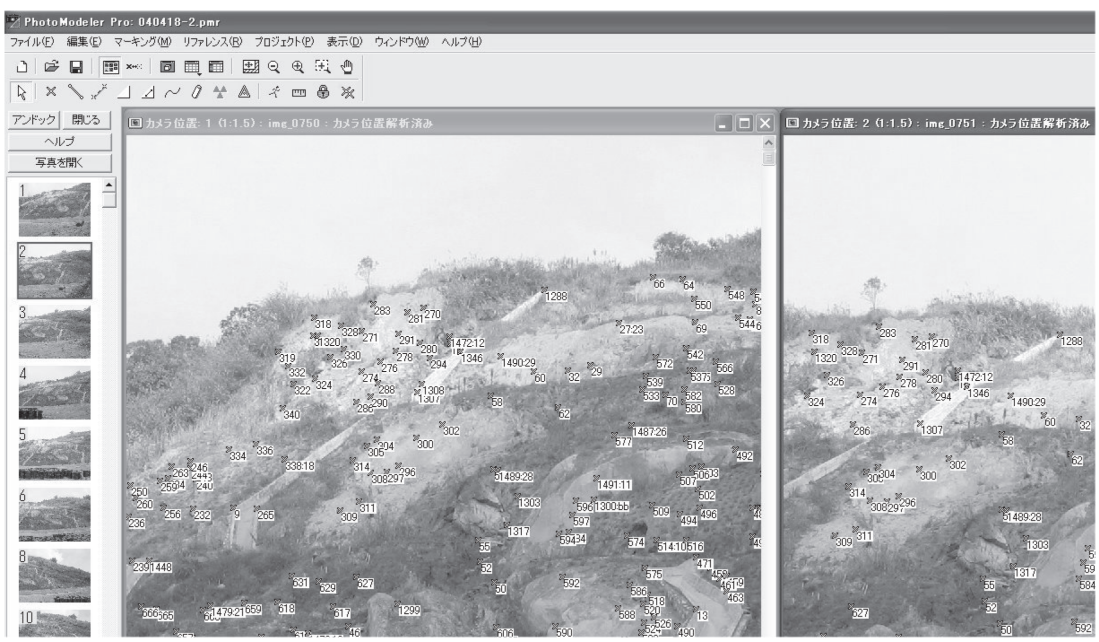


Figure 6: Database using Photomodeler

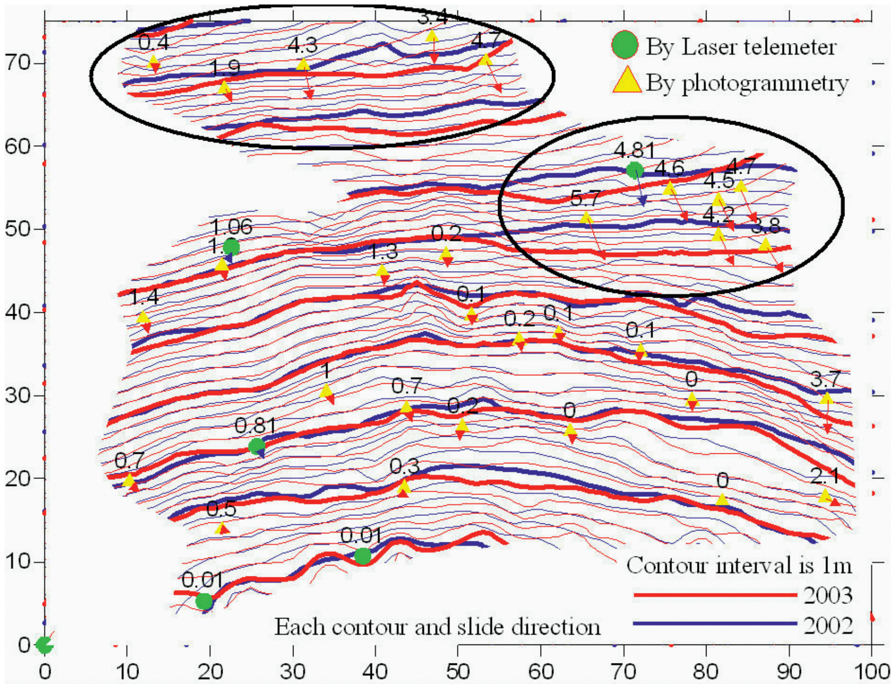


Figure 7: Results 1

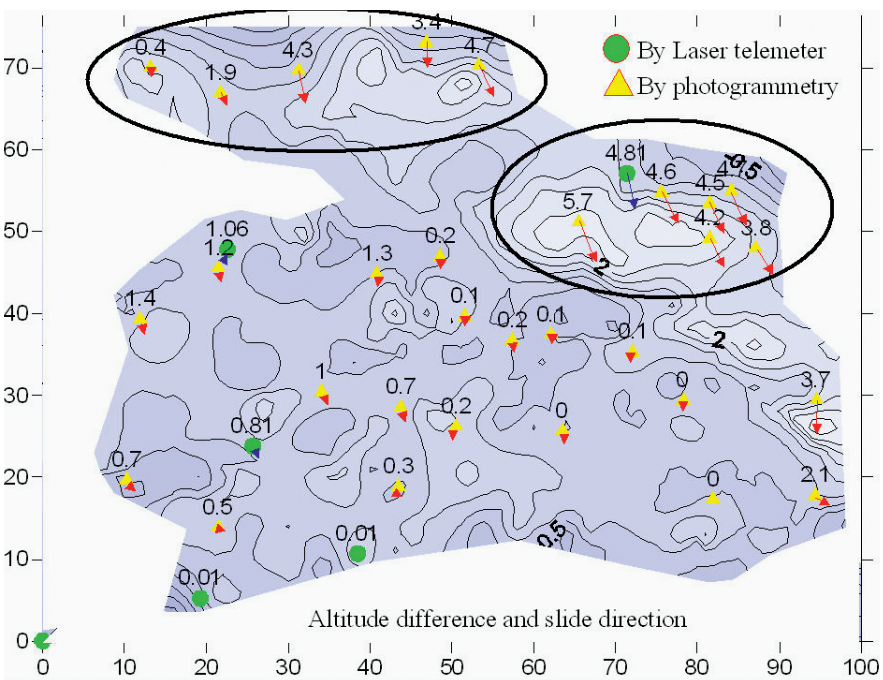
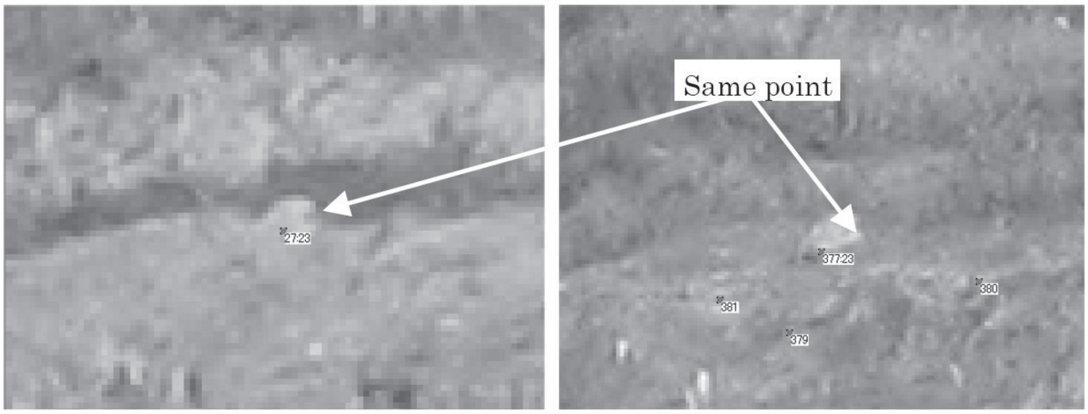


Figure 8: Results 2



(a) The point 23 in 2002 (a) The point 23 in 2002

Figure 9: The coordinates of the same point

Table 1: The reference points by laser telemeter

	2002			2003		
	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)
P2	0.00	0.00	0.00	0.00	0.00	0.00
P4	19.25	5.23	−0.74	19.26	5.23	−0.74
P3	38.48	10.66	−0.24	38.47	10.65	−0.24
P5	25.69	23.82	9.91	25.97	23.06	9.52
P9	22.59	47.82	26.44	22.76	46.77	25.88
P8	71.37	57.10	29.34	73.82	52.96	27.90

Table 2: The result by Photomodeler

	2002			2003			2002-2003			
ID	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	S (m)
1	81.93	17.25	5.39	81.92	17.25	5.39	0.01	0.00	0.00	18.07
2	78.25	29.38	11.81	78.24	29.34	11.84	0.01	0.04	−0.03	31.64
3	87.18	47.99	24.17	89.24	44.74	23.53	−2.06	3.25	0.64	50.59
4	81.49	49.20	23.79	83.33	45.43	23.30	−1.84	3.77	0.48	51.09
5	72.17	35.27	15.72	72.13	35.41	15.69	0.04	−0.14	0.04	38.73
6	94.50	29.47	14.25	94.67	25.75	13.95	−0.17	3.72	0.29	29.29
7	63.50	25.67	8.84	63.49	25.70	8.80	0.00	−0.03	0.04	27.17
8	62.16	37.46	16.21	62.10	37.56	16.15	0.07	−0.10	0.05	40.88
9	75.57	54.76	28.62	77.68	50.63	27.52	−2.11	4.13	1.11	57.66
10	57.41	36.69	15.02	57.43	36.51	14.77	−0.03	0.18	0.26	39.38
11	51.68	39.65	19.13	51.62	39.68	19.06	0.06	−0.04	0.07	44.02
12	13.20	69.98	42.63	12.80	70.08	42.63	0.39	−0.09	−0.01	82.03
13	43.82	28.51	10.18	44.04	27.85	9.74	−0.22	0.65	0.43	29.51
14	94.42	17.78	8.11	96.28	16.89	8.19	−1.86	0.90	−0.08	18.86
15	84.24	55.01	28.20	86.26	50.80	26.62	−2.02	4.22	1.58	57.39
16	11.92	39.31	22.52	12.29	38.01	21.68	−0.36	1.30	0.84	43.76
17	10.29	19.62	10.17	10.82	19.22	9.95	−0.53	0.40	0.22	21.65
18	21.50	45.56	25.13	21.70	44.42	24.42	−0.20	1.14	0.71	50.69
19	43.53	18.90	4.23	43.81	18.74	4.13	−0.28	0.15	0.10	19.20
20	50.54	26.24	8.39	50.51	26.08	8.24	0.03	0.16	0.15	27.35
21	34.07	30.36	12.30	34.38	29.45	11.87	−0.32	0.90	0.43	31.76
22	21.43	13.90	3.59	21.92	13.80	3.42	−0.50	0.09	0.17	14.23
23	31.23	69.71	40.44	32.04	65.46	37.81	−0.80	4.25	2.62	75.60
24	46.88	73.09	41.94	46.83	69.65	40.79	0.05	3.45	1.15	80.71
25	53.32	70.29	38.65	55.26	66.04	37.11	−1.94	4.26	1.54	75.78
26	48.60	46.93	24.13	48.49	47.07	24.06	0.11	−0.14	0.07	52.87
27	65.48	51.17	25.88	67.58	45.87	24.44	−2.10	5.30	1.44	52.02
28	40.89	44.88	21.97	41.04	43.58	21.28	−0.15	1.29	0.69	48.50
29	21.73	66.91	38.52	22.45	65.17	37.18	−0.72	1.74	1.34	75.03
30	81.57	53.40	27.25	83.50	49.31	26.03	−1.93	4.09	1.22	55.79

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