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Verification of Early Impacted Area Estimation Method Using DMSP/OLS Night-time Imagery on the Basis of Field Survey

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Synopsis

In this paper, we verify the method to estimate impacted area using night-time imagery data captured by sattelite proposed by Kohiyama et al.(1999). Kohiyama et al. estimated the possible impacted area of 1999 Marmara earthquake disaster in Turkey based on their method. We conducted a field survey in the impacted area in Turkey to verify their estimation. As a result, it was clarified that the estimation is effective to detect impacted area in 7.2km×7.2km unit, and that their estimation can detect various kinds of damages rather than only severe housing damages.

Keywords: the 1999 Marmara earthquake disaster, DMSP/OLS night-time imagery, Early impacted area estimation, Field survey

1. INTRODUCTION

In case of large earthquake, it is very important to grasp gross overview of impacted area for deploying limited human and material resources adequately. Kohiyama et al. (1999) developed a method to estimate impacted area using night-time imagery captured by DMSP/OLS (Defense Meteorological Satellite Program/ Optical Linescan System) to address such needs of disaster managers. They assumed that the light intensity of the area would decrease if the buildings collapse or blackout happens due to the earthquake. Those areas which light intensity after the earthquake decreased significantly were estimated as the impacted area.

This method was applied for the Marmara earthquake disaster in Turkey (Aug. 1999) and it seems to identify the damaged cities successfully such as Yalova, Izmit, and Adapazari along the fault rupture. This method could also identify cities such as Bolu and Eskshier located 200-300 km away from the fault rupture. However, the meaning of significant decrease in light intensity after the earthquake should be ascertained by examining what actually happened in the area estimated to be impacted. It could be various types of suffering from the natural disaster. Some people might lose their homes, some people might suffer disruption of lifelines and some people might just have a fear of aftershocks. It is needed to find out what types of events due to the earthquake reflected in the significant decrease in light intensity by a field investigation.

The purpose of this study is 1) to verify what pattern of suffering due to the Marmara earthquake disaster was identified as the impact of the disaster in the estimation and 2) to assess the accuracy of the estimation.

2. METHOD TO VERIFY

Verification process has two stages. At first, we conducted a field survey in the impacted area in Turkey. In the field survey, we recorded the longitude and the latitude of the damages due to the earthquake with the GPS. Second, we overlaid distribution of observed damages onto the damage estimation results to assess the accuracy of estimation.

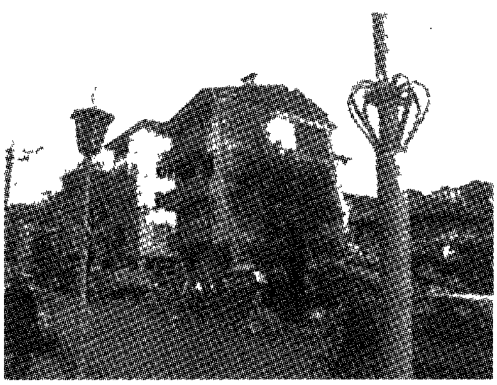
2.1. Method of field survey

The field survey in Turkey was conducted from October. 27 to October. 29 and October. 31, 1999. **Table 1** shows the survey schedule. We set survey route connecting major impacted cities, Sakarya (Adapazari), Degilmendere, Golcuk, Kocael (Izmit), Yalova, Bursa and Eskhier. Along the survey route, we measured the longitude and the latitude of the damages we observed with GPS (MAGELLAN GPS-315).

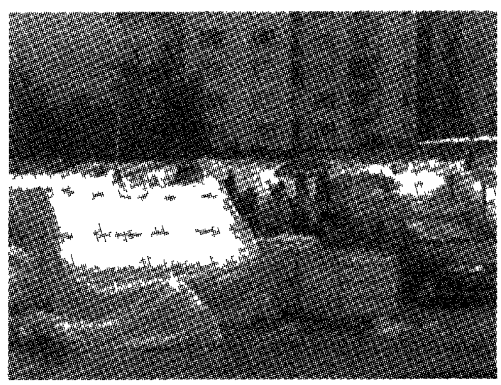
Through the ground observation in Marmara region, we could record the following five different damages due to the earthquake, 1) damaged structures, 2) demolished structures, 3) tent villages, 4) tent blocks and 5) tents around building structures with no apparent damages. **Fig. 1** shows the exam-

Table 1 Survey schedule

Data	Surveyed Area/ Cities
Oct. 27, 1999	Suburban area of Istanbul (Avcılar, Zeytinburnu, Merter)
Oct. 28, 1999	North coast of Izmit Bay, Sothern part of Sapanca Lake, Sakarya(Adapazari)
Oct. 29, 1999	Izmit Bay area, Degilmendere, Golcuk, Kocaeli(Izmit)
Oct. 30, 1999	---
Oct. 31, 1999	Yalova, Bursa, Eskisehir



1)damaged structures and 2)demolished structures



3) tent village

4) tent block

5) tents around building structure with no apparent damages

Figure 1 The examples of each damages

ples of each damages. Damaged structures mean collapsed or apparently damaged structures. Demolished structures mean rubble-strewn vacant lots left after demolition. The existence of damaged or demolished structures could tell us that the area was severely impacted by the earthquake. Tent villages mean mass of tents for evacuation deployed at public space such as parks in a organized manner. Tent blocks means groups of tents smaller in number than tent villages located in more tight place. The existence of these two types of tents could show indirectly that the area was impacted. On the other hand, the existence of tents around building structures with no apparent damages could tell us that people in the area felt a great deal of fear as to the safety of their houses, even they show no apparent damages. Although difference of three types of tents is not distinct, we can see the level of suffering at each area from these signs. **Fig. 2** shows the qualitative relationship between signs left in the impacted area and the level of impact. **Fig. 3** shows survey route, distribution of observed damages

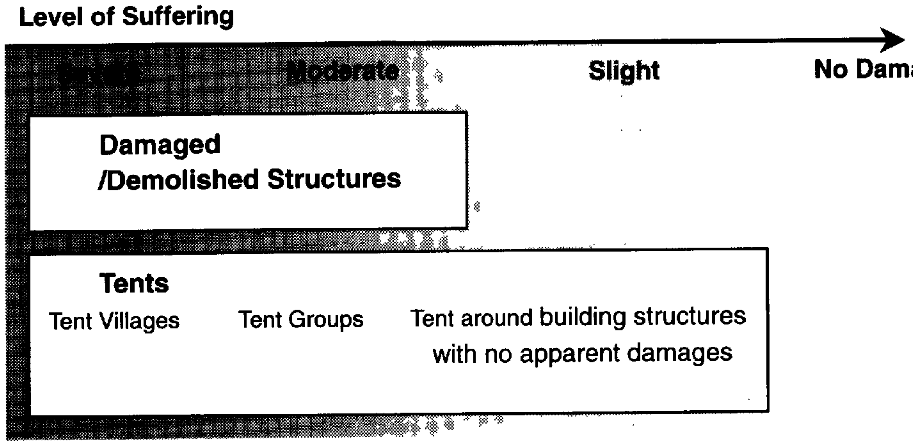
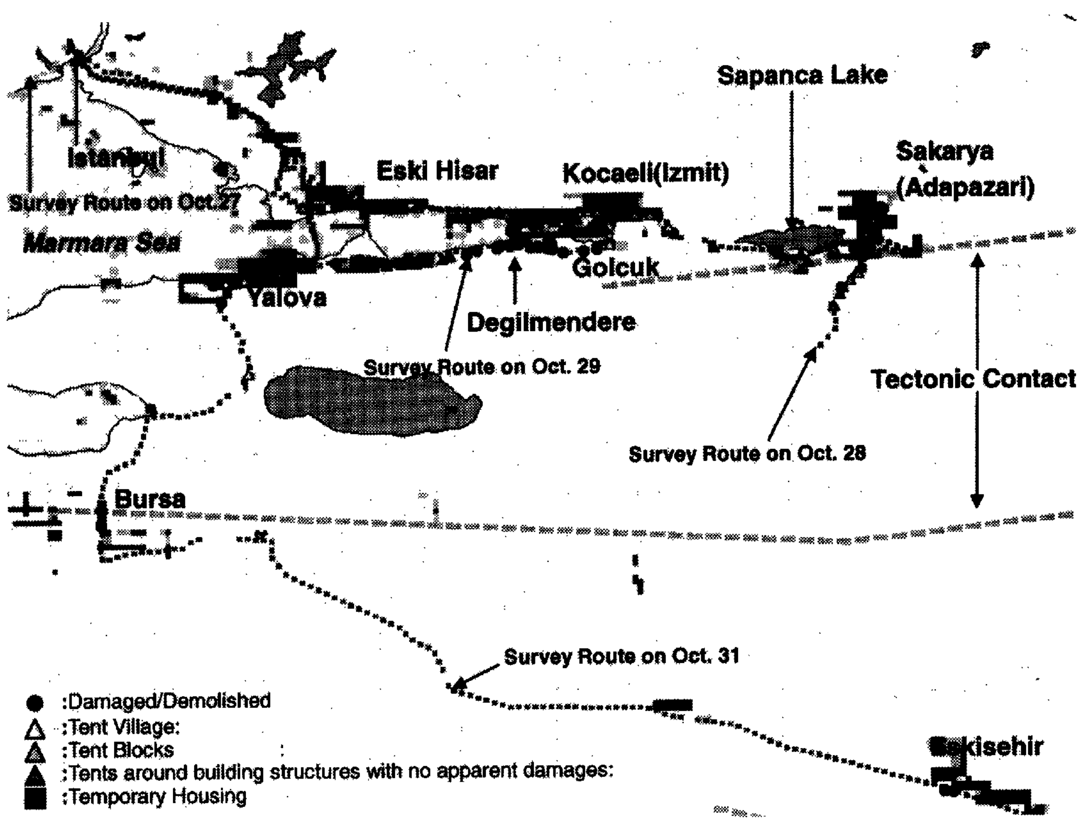


Figure 2 Relationship between damages left in the impacted area and the level of suffering



Figures 3 Survey route and comparison between the field observation and the estimation

through field survey and estimated damaged area. The estimation seems to detect the damages well.

2.2. Result of field survey

On October 27, we surveyed Avcılar, Zeytinburnu and Merter, suburban area of Istanbul. We could see demolished buildings there. Since this area was out of the DMSP estimation, whether these damages were identified unfortunately could not be checked.

On October. 28, we went along north coast of Izmit Bay and went through south of Sapança Lake and surveyed Sakarya (Adapazari). We could see tents around building structures with no apparent damages along north coast of Izmit Bay and south of Sakarya. In Sakarya, we could see many damaged buildings, demolished buildings and large tent villages. In the estimation, western part of Sakarya was detected as impacted area. Then, we visited temporary houses supported by Japanese government located at the south of Sakarya. We could also see several temporary houses on the way to Sakarya.

On October. 29, we crossed Izmit Bay from Eski Hisar by ferry boat, and went around Izmit Bay in a counterclockwise direction. On the south of Izmit Bay, we could see damaged residences, broken tower of mosque and tents around building structures with no apparent damages. In Degilmendere, part of the city along the sea subsided under the sea. Ground subsidence was also observed in Golcuk, reported as one of the most impacted cities. In Golcuk, we could see clear ground surface rupture, large vacant places left after demolition and large tent villages. In fact, Golcuk was not identified as impacted area in the estimation, but the sea off the Golcuk was identified as impacted area. Then, we visited Tupuras oil refinery burned due to the earthquake. In the refinery, we could see several burned oil tanks and a broken timney.

On October. 31, we crossed Izmit Bay again, and went through Yalova, Bursa and Eskisehir. In Yalova, we could see many demolished buildings and tent villages. Impacted area around Yalova was detected clearly in the estimation. In Bursa and Eskisehir, a few damaged/demolished structures were observed. In the estimation, Bursa was detected clearly but Eskisehir was not. Neighboring area on the north-east of Eskisehir was detected as the impacted area.

As a result of field survey, it can be seen that northern part of real impacted area tends to be detected as impacted area in their estimation. However, it seems to grasp the damaged cities successfully as a whole.

2.3. Checking Field Observation against Estimation

Results of observed damage distribution by the field survey was checked against estimated as follows. At first, estimated area was meshed. Then, we checked whether each mesh on the survey route includes the observed damages such as damaged/demolished structures and whether the mesh includes grids estimated as impacted area. There could be four types of meshes on the survey route as shown in **Fig. 4**.

A. Meshes including both observed damages and estimated damages
B. Meshes including only observed damages but no estimated damages.
C. Meshes including only estimated damages but no observed damages.
D. Meshes including neither observed damages nor estimated damages

We can judge the estimation to be correct in the meshes of type A and D and to be incorrect in the meshes of type B and C. Number of each types of mesh was counted and the significance of the estimation was tested statistically using chi-square test.

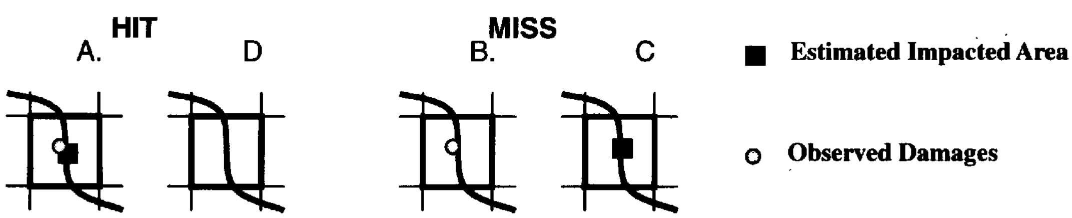


Figure 4 Four types of meshes on the survey route

To verify what was detected as the impact of the disaster in the estimation, two different kinds of damages were considered. One is the distribution of only damaged/demolished structures and the other is that of all damage indices including tents. In addition, to test the sensitivity of the estimation, mesh size was systematically varied in the following five units 0.9km × 0.9km (minimum unit of the estimation), 1.8km×1.8km, 3.6km×3.6km, 7.2km ×7.2km and 14.4km×14.4km.

3. RESULT OF CHECK

3.1. Significance of the estimation

Detailed data in each check and result of chi-square test for each mesh size were shown as **Table 2**. As result of the chi-square test, the significance of the estimation was supported in every mesh size and in both kinds of damages.

Table 2 Detailed data in each check and result of chi-square test

Result of the esitimation by Kohiyama et al. (1999)		Result of Field Survey: Only Damaged/Demolished Structures					All Damage Indicators				
		Observed	Not Observed	Total	χ^2-value	ϕ	Observed	Not Observed	Total	χ^2-value	ϕ
0.9km × 0.9km	Impacted	17	182	199	9.07	0.087	37	162	199	37.30	0.176
	Not Impacted	37	967	1001			58	943	1001		
	Total	54	1146	1200			95	1105	1200		
1.8km × 1.8km	Impacted	20	90	110	29.07	0.216	38	72	110	76.32	0.351
	Not Impacted	21	490	511			30	481	511		
	Total	41	580	621			68	553	621		
3.6km × 3.6km	Impacted	24	67	91	23.45	0.301	42	49	91	43.57	0.410
	Not Impacted	9	159	168			17	151	168		
	Total	33	226	259			59	200	259		
7.2km × 7.2km	Impacted	16	21	37	38.88	0.521	22	15	37	57.17	0.632
	Not Impacted	3	103	106			4	102	106		
	Total	19	124	143			26	117	143		
14.4km × 14.4km	Impacted	11	12	23	16.63	0.540	14	9	23	23.74	0.645
	Not Impacted	1	33	34			1	33	34		
	Total	12	45	57			15	42	57		

3.2. Characteristics of the estimation

Figure 5 shows the relationship between the four-fold point correlation coefficient (ϕ coefficient) and mesh size, damage types in each check. From the result shown in **Fig. 5**, the following two things concerning the characteristics of the estimation were revealed.

Firstly, As shown in **Fig. 5**, the larger the mesh size is, the larger the ϕ coefficient is in both damage type. Additionally, the grow rate of coefficient gets small over the mesh size of 7.2km×7.2km. As a result, it can be seen that appropriate mesh size for the estimation may be 7.2km×7.2km. This result suggests the DMSP estimation may be reliable for the detection of major impacted cities.

Secondly, the ϕ coefficient of the test detecting all kinds of damages including tents is larger than that of the test detecting only damaged/demolished structures. This means their estimation can detect whole impacted area rather than only severely impacted area.

4. CONCLUSION

In this paper, we tested the reliability of the estimation by Kohiyama et al. through field survey, quantitatively. As a result, it was clarified that 1) significance of their estimation was supported, that 2) the estimation is effective to detect impacted area in 7.2km×7.2km unit, and that 3) their estimation can detect various kinds of damages rather than only severe building damages.

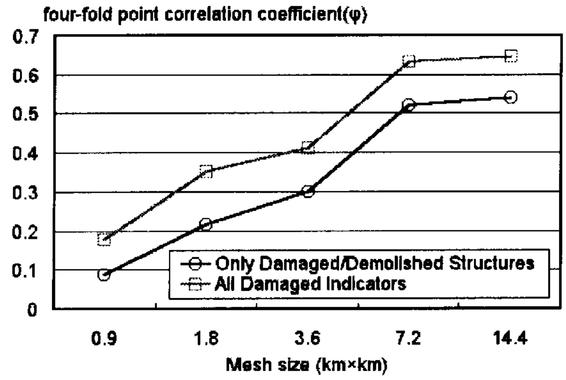


Figure 5 The relationship between the four-fold point correlation coefficient (ϕ coefficient) and mesh size, group of damage indicators

There could be various types of damages besides the five damage indicators mentioned above such as lifeline disruption, especially, black out which can be reflected directly on the DMSP data. It is important for further study to understand the effect of light intensity reduction due to the blackout. That may help to improve the ϕ coefficient of each check.

REFERENCES

Kohiyama M. et al. (1999): "Early estimation of earthquake damaged area based on the DMSP night-time images", *Proceedings of the Annual Conference of the Institute of Social Safety Science*, 9, pp86-89.

要　旨

本研究では、小檜山・他(1999)の提案する衛星が捉える夜間可視画像を用いた早期被災地推定手法の検証を行った．検証は，小檜山・他が行ったトルコ・マルマラ地震(1999)の被災地の推定結果と，筆者らがトルコで行った現地調査の結果を照合する形で行った．その結果,小檜山･他の推定手法が,7.2km×7.2km メッシュ単位以上での被災地判定に適していること，また，重度の建物被害だけでなく，より軽度の被害も含めた被害を捕捉していることが明らかになった．

キーワード：1999 年トルコ・マルマラ地震，DMSP/OLS 夜間可視画像，早期被災地推定，現地調査