

**EARTHQUAKE INFORMATION SYSTEM: A CROWDSOURCING
MOBILE APPLICATION TO INFORM AND GATHER DATA**

by

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MOBILE APPLICATION TO INFORM AND GATHER DATA

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One last word for my son, Can. I wish he always pursues his dreams, no matter how long it takes, how hard it seems. If there is a will, there is a way...

ABSTRACT

EARTHQUAKE INFORMATION SYSTEM: A CROWDSOURCING MOBILE APPLICATION TO INFORM AND GATHER DATA

It has been observed that large earthquakes, which have taken place in Turkey and around the world during the last 10 years, could cause great social and economic losses in centers that are densely populated. It is crucial that regions, which had been affected by the earthquake, should be identified fast and in the correct way in order that search, and rescue activities could be carried out effectively.

Evaluation of place and level of damage promptly following a destructive earthquake through the data received from emergency intervention systems could facilitate the earthquake emergency response process. In this respect, numerous institutes around the world have introduced on-line earthquake intensity surveys in order to establish internet based macro-seismic maps and hence to determine the regions that are affected by the earthquake the most. The purpose of the surveys is to establish earthquake intensity map immediately after the earthquake by collecting macro-seismic intensity data from the people who feel the earthquake.

This project aims to collect this information from the individuals, spread around Turkey, using a mobile application which works both ways: One part of the application gives information about the recent earthquakes, seismicity history of the current location of the user, individual's distance to epicenter etc. The other part of the application lets the user to provide KOERI how he/she felt the earthquake by answering some multiple-choice questions. While answering these questions, the application also records the geographic location of the user. This information is then stored in the central database and can be used for further analysis of the impact of the earthquake and for fine-tuning the instrumental intensity maps.

ÖZET

DEPREM BİLGİ SİSTEMİ: BİLGİ VERMEK VE BİLGİ TOPLAMAK İÇİN GELİŞTİRİLMİŞ BİR MOBİL KİTLE KAYNAK UYGULAMASI

Son on yıl içinde gerek Türkiye gerekse Dünya'nın farklı yerlerinde gerçekleşen büyük depremlerin yoğun nüfusun yaşadığı bölgelerde büyük sosyal ve ekonomik kayıplara neden olduğu açıktır. Büyük bir deprem gerçekleştiğinde depremden en çok etkilenen bölgelerin belirlenmesi ve arama – kurtarma aktivitelerinin yoğunluğunun buna göre doğru şekilde planlanması etkin bir çalışmayı beraberinde getirecektir.

Acil müdahale sistemlerinden alınan bilgiler eşliğinde, yıkıcı bir depremin hemen ardından yıkımın büyük olduğu bölgelerin doğru olarak belirlenmesi acil müdahale ekiplerine doğru kaynak planlaması için yardımcı olacaktır. Bu bağlamda, Dünya'nın dört bir yanında enstitüler internet tabanlı makro-sismik haritalar çıkartabilmek için internet tabanlı anket sistemlerini hayata geçirmekte ve bu yolla depremden en fazla etkilenen bölgelerin tespitini sağlamak için çalışmalar yürütmektedir. Bu anketlerin amacı depremden hemen sonra depremden etkilenen bireylerden toplanan bilgiler ışığında bir deprem şiddet haritası çıkartabilmektir.

Bu projenin amacı iki yönlü çalışan bir mobil uygulama sunmak ve onları hem bilgilendirmek hem de yukarıda sözü edilen bilgileri toplamaktır. Uygulamanın bir bölümünde kullanıcılara en son depremler hakkında bilgi verilmekte, Türkiye'nin herhangi bir noktasının veya buldukları konumun sismik geçmişi gösterilmektedir. Diğer bölümünde ise kullanıcılar bir deprem sonrasında bu uygulamanın kitle kaynak anketini kullanarak belli sorulara yanıt vermekte, bu yanıtlar ışığında depremi nasıl ve ne şiddette hissettiklerini belirtmektedir. Bu bilgiler, anketi yanıtlayan bireyin coğrafik konumu ile beraber merkezi veri tabanına kaydedilmektedir. Toplanan veriler pratik bir arabirim ile veritabanı dışına istenen formatta çıkarılabilmektedir. Bu veriler araştırmacılar tarafından aletsel şiddet haritalarının iyileştirilmesinde kullanılabilir.

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LIST OF ACRONYMS

CII	: Community Internet Intensity
CSV	: Comma Separated Values
CWS	: Community Weighted Sum
EIS	: Earthquake Information System
ELER	: Earthquake Loss Estimation Routine
KOERI	: Boğaziçi University Kandilli Observatory and Earthquake Research Institute



1. INTRODUCTION

Importance and requirement of emergency intervention systems in Turkey have increased especially after the 1999 Kocaeli Mw=7.4, 1999 Duzce Mw=7.2 and 2011 Van Mw=7.2 earthquakes. Emergency intervention immediately after the destructive earthquakes is vital in terms of the rescue and repair activities following the disaster. The works of Coburn and Spence in 2002 have indicated that insufficient emergency actions following an earthquake could increase loss of lives by 10-fold (Coburn and Spence, 2002). This in turn, establishes that obtaining estimations for the earthquake, aftershocks and for the losses and damages simultaneously would be the requirement.

Numerous seismological institutes around the world are providing earthquake damage and loss estimations rapidly after an earthquake by introducing internet based macro-seismic survey studies. Macro-seismic intensity maps are established by analyzing survey results in real time.

1.1. Objectives

The main objective of this thesis is to develop a mobile application that contains a macro-seismic survey which can be used to gather data from the users immediately after the occurrence of an earthquake.

The second objective of this application is to give the users information about recent earthquakes happened in Turkey. The information contains the magnitude, date-time of occurrence, location of the epicenter and depth of the earthquake. In addition to this information, the application gives information about the seismic history of Turkey which will be discussed further in detail in the following chapters of the thesis.

The mobile application is named Deprem Bilgi Sistemi (EIS - Earthquake Information System) and is currently made available for both iOS and Android platforms on the respective application markets.



2. INTERNATIONAL INTERNET BASED MACRO-SEISMIC SURVEYS

The greatest advantage of the internet based survey system is to be able to have the information about how the human beings had been affected from the disaster, about the effects of the earthquake and the level of the damage in a few minutes after the earthquake (USGS, 2013a). The intensity maps, which are established with the help of these data, display a clear and detailed image of how the earthquake affected the area on the local scale. Several institutions around the world developed tools to conduct internet based macroseismic surveys.

2.1. U.S. Geological Survey

“Did You Feel It®” (DYFI) system of the U.S. Geological Survey collects shock and damage reports from internet users automatically immediately after an earthquake. The DYFI system is a system that is used around the world including fast and wide ranging macro-seismic data source, and which can supply intensity information about the earthquake shakes that take place in USA and in other countries both quantitatively and qualitatively.

Community Internet Intensity Map has been officially produced in California in 1997 for the first time following the analysis of responses received for the surveys and has been defined by Wald et al. (1999) for the very first time. The system has been improved substantially during the later years and it has started to be used. DYFI has been made widely available throughout USA in 2000 and the global macro-seismic data archive was created in 2004 (Wald, et al, 2011). Instrumental and community intensity map, which has been produced following the 2013 Mw 5.8 East Honshu earthquake, is shown in Figures 2.1 and 2.2 (USGS, 2013b).

The DYFI data that is obtained by surveys has been found extremely useful for rapid post-earthquake information (Atkinson and Wald, 2007). Describing the ground motion

effects qualitatively, these data can be used for quantitative scientific studies. The work of Atkinson and Wald (2007) analyzes relationship between DYFI data and earthquake ground motions and in conclusion states that these new data on earthquake ground motions offer a valuable new data resource.

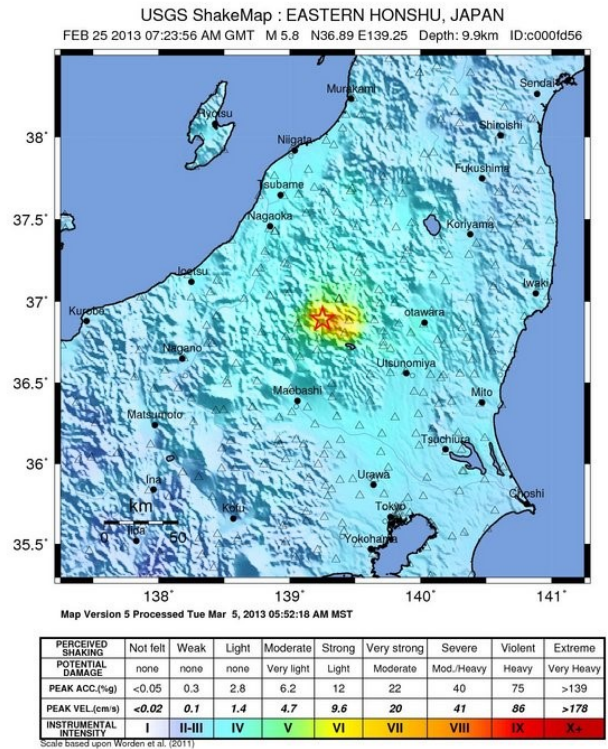


Figure 2.1. Instrumental Intensity Map.

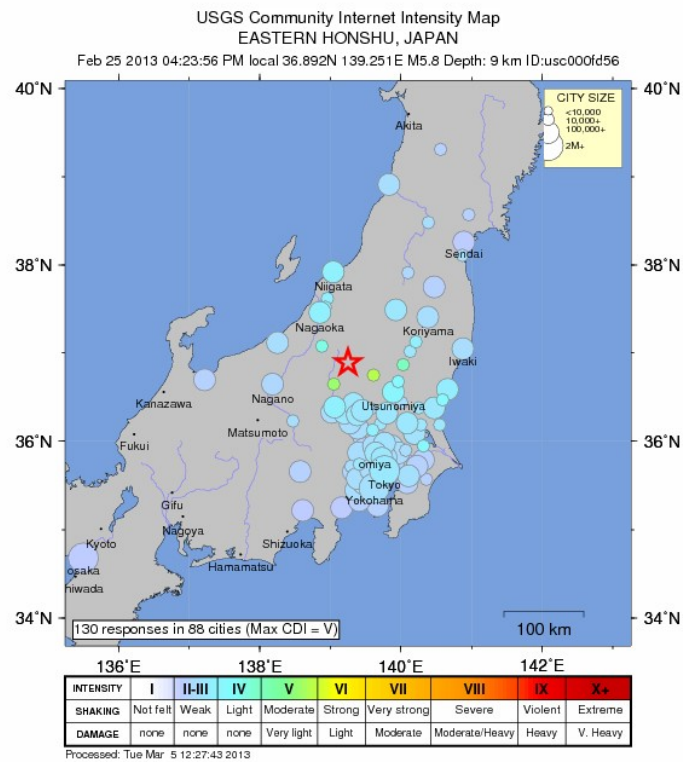


Figure 2.2. Community Intensity Map.

2.2. New Zealand Geonet Perception Report

The GNS Science (<http://www.geonet.org.nz>) online system has been operational in New Zealand since 2004. GNS internet interface is an interactive interface, which shows both the instrumental and the macro-seismic intensity. The GNS automatic system submits only the earthquakes with magnitudes up to the value of VIII. The GNS can also provide access to a query system, which is based on the date and time of the earthquake, for the internet users (Wald, et al., 2011).

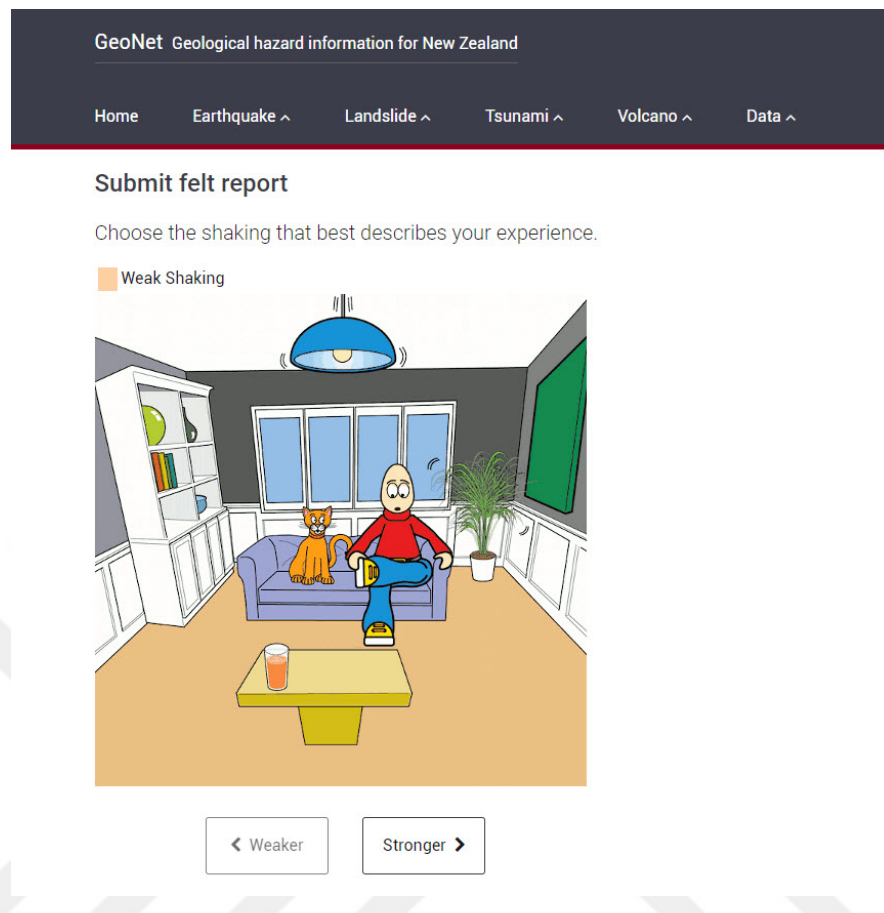


Figure 2.3 GeoNet Geological hazard information for New Zealand macro-seismic survey.

2.3. INGV (Istituto Nazionale di Geofisica e Vulcanologia, National Geophysics and Vulcanology Institute, Italy)

The internet based macro-seismic data collection system for Italy (“Did you feel the quake?”/“Hai Sentito il Terremoto”: <http://www.haisentitoilterremoto.it>) has been in operation since 2007 (Figure 2.4). In this system, the most probable macro-seismic rating is designated for each of the inputs as the result of the individual responses and addition of their analyzed results. Variance of average intensity weight, that is available for the data sources is used in order to eliminate inconsistent inputs (Sbarra et al., 2010). In addition to this, data are not taken into account if these exceed the previously determined limits of the intensity estimation equations, which are the functions of the magnitude and the

distance, selected for that area. Following this, averages for the appointed intensity values are calculated for each of the cities and villages (Wald et al., 2011).

Figure 2.4 The internet based macro-seismic data collection system for Italy.

2.4. EMSC (European-Mediterranean Seismological Centre)

The online survey system (<http://www.emsc.eu/Earthquake/felt.php>), which is available at the European-Mediterranean Seismological Centre has been operational since 2004. The system provides its services in 32 different languages (Figure 2.5).

British Geological Survey, Le Bureau Central Sismologique Français, Ministry of Natural Resources of Canada, Swiss Seismological Service can be included amongst other institutes that perform internet based macro-seismic surveys around the world other than the ones mentioned in this section.



Figure 2.5 European-Mediterranean Seismological Centre macro-seismic survey.

2.5. ELER (Earthquake Loss Estimation Routine)

ELER Software is a rapid loss estimation tool developed with researchers from Boğaziçi University-Kandilli Observatory and Earthquake Research Institute (KOERI), Imperial College (IC), NORSAR and Euro-Mediterranean Seismological Center (EMSC). The aim of this tool is to enable effective emergency response and public information.

Intensity maps created by ELER after an earthquake is automatically displayed on the web page of KOERI (<http://www.koeri.boun.edu.tr/sismo/2/son-depremler/siddet-haritalari>). An example intensity map automatically created by ELER after BODRUM

earthquake dated 21.07.2017 is shown in Figure 2.6. Public data that are gathered from macro seismic surveys can be incorporated into these kinds of routines to further fine-tune the intensity maps.

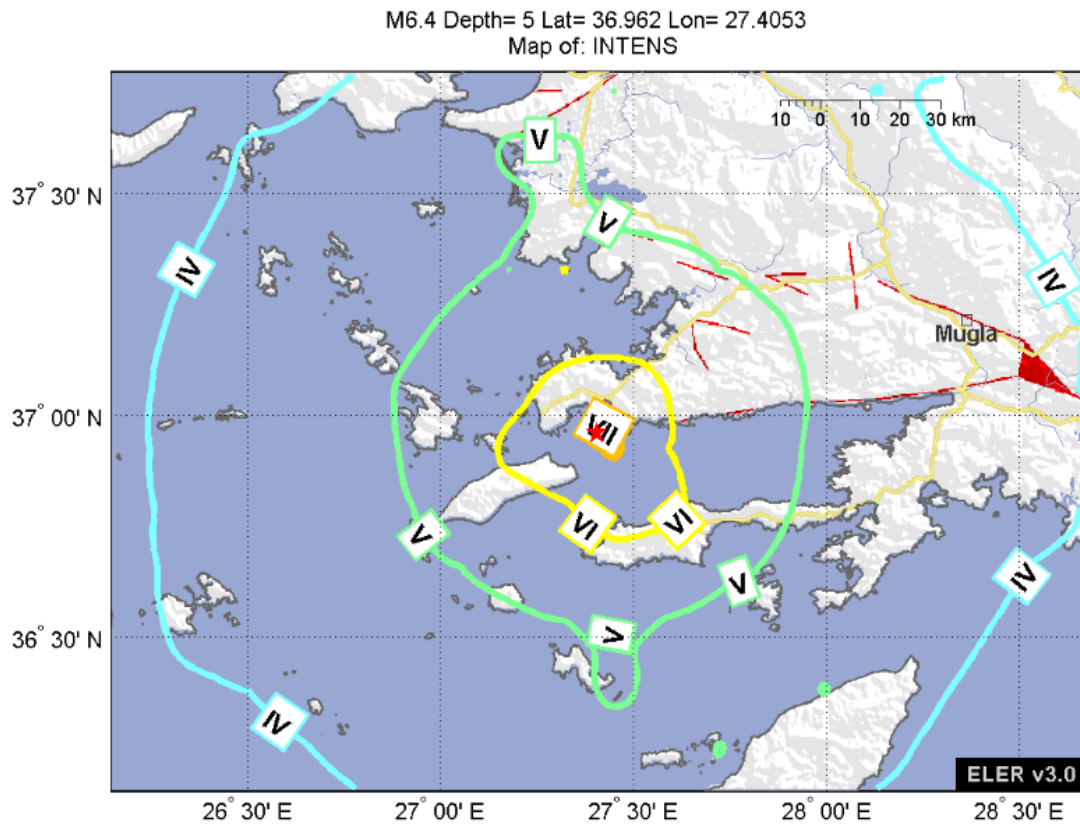


Figure 2.6 Intensity map automatically created by ELER after BODRUM earthquake dated 21.07.2017

3. NATIONAL INTERNET BASED MACRO-SEISMIC SURVEY

The Earthquake Information System which is prepared for this project is a mobile application which works both for IOS (iPhone, iPad) and Android smart phones and Android tablets. This mobile application is available for all of the internet users at the moment, but the survey questions are available only in Turkish language at this stage. The purpose of this system is to gather information from the users who felt a recent earthquake by asking survey questions. The answers to the questions, along with the time, date and geographical location of the users are recorded in a database which resides on KOERI premises. A special interface is also provided for researchers, which enables to filter the results according to earthquakes.

In order to encourage the usage of the mobile application and increase the user base, the application also has two main sections apart from the survey section. The first section gives information about the latest earthquakes occurred in Turkey. Users can click on the earthquakes in the list and get detailed information (the date, time and magnitude of the earthquake, the place of epicenter of earthquake on Turkey map, intensity map of the earthquake) about the selected earthquake. Additionally, the user can check the seismic history of Turkey in another section of the application. He/she can click on anywhere in the Turkey map and learn about the earthquakes that occurred inside 100 kilometers radius of the clicked location. Plus, he/she can learn about the seismic history of the location he/she is on at that very moment. The earthquake history of the database of the application contains all the earthquakes with magnitudes larger than 4, recorded since year 1900.

The general overview of the mobile application is shown in Figures 3.1 through Figure 3.5.



Figure 3.1 General overview of the mobile application.



Figure 3.2 Recent earthquakes list.

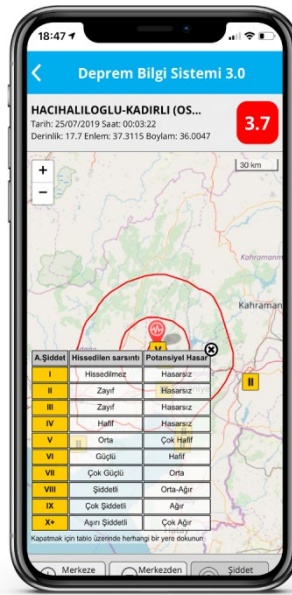


Figure 3.3. Information about the selected earthquake.

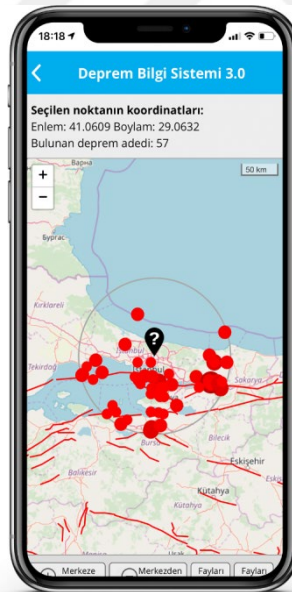


Figure 3.4. Seismic history of a selected location.



Figure 3.5 Macro-seismic survey.

The data display system, which will be discussed later in this thesis displays the location of the users who responded to the selected earthquake and computes the CII (Community Internet Intensity) for each user and the mean CII for the individual earthquake based on the results gathered from the surveys. Figure 3.6 show the data display system that can be utilized by researchers.

Kimlik	felt	reaction	stand	shelf	picture	furniture	damage	ELL	depremitat	depremiton	tarix	depremcenzer	depremtarix	depremtat	userlat	userlon	mag	
83557	5	5	3	1	1	1	1	5.4	36.9620	27.4053	21.07.2017 06:44:00	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3539886	27.3281512		
83556	5	5	3	1	1	1	1	5.4	36.9620	27.4053	21.07.2017 06:44:00	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3539886	27.3281512		
83555	5	5	3	1	1	1	1	5.4	36.9620	27.4053	21.07.2017 06:44:00	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3539886	27.3281512		
83554	5	5	3	1	1	1	1	5.4	36.9620	27.4053	21.07.2017 06:44:00	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3539886	27.3281512		
83552	5	5	4	2	2	2	1	6.9	36.9620	27.4053	21.07.2017 06:27:20	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	38.3858541	27.1234075		
83551	5	4	2	2	1	1	1	5.4	36.9620	27.4053	21.07.2017 06:27:03	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3845515	27.2706542		
83549	5	5	3	2	1	1	1	5.8	36.9620	27.4053	21.07.2017 06:15:11	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	36.6881656	28.1187775		
83548	5	3	3	2	1	2	1	5.9	36.9620	27.4053	21.07.2017 06:14:49	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.0177635	28.3020136		
83544	1	5	4	2	3	2	2	7	9.8	36.9620	27.4053	21.07.2017 06:01:09	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	36.9902324	27.3270278	
83543	5	5	2	2	1	1	1	5.6	36.9620	27.4053	21.07.2017 06:00:38	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.1347179	27.5796297		
83542	4	3	1	1	1	1	1	4.6	36.9620	27.4053	21.07.2017 05:52:25	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.0485391	30.1978388		
83538	5	5	4	2	1	1	1	6.0	36.9620	27.4053	21.07.2017 05:40:36	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.3702947	27.2668831		
83534	2	4	2	2	1	2	1	5.2	36.9620	27.4053	21.07.2017 05:39:31	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	36.8707923	28.2664485		
83533	5	4	2	1	1	2	1	5.4	36.9620	27.4053	21.07.2017 05:32:52	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.2158282	28.3668307		
83532	2	4	2	2	1	2	1	5.2	36.9620	27.4053	21.07.2017 05:32:49	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	36.8707923	28.2664485		
83528	5	5	1	2	3	3	2	8.2	36.9620	27.4053	21.07.2017 05:30:31	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.0444676	27.39139		
83525	5	5	2	2	1	1	1	5.8	36.9620	27.4053	21.07.2017 05:26:05	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.2826206	27.5979272		
83522	5	5	5	2	1	2	2	6.8	36.9620	27.4053	21.07.2017 05:25:26	GOKOVA KOPFEZİ (AKDENİZ)	21.07.2017	01:31:09	37.1871977	27.5528802		

Figure 3.6 Data display system interface, based on the results of the surveys gathered from mobile users.

3.1. EIS Application workflow

EIS (Earthquake Information System) utilizes the earthquake data from KOERI's Regional Earthquake-Tsunami Monitoring Center. EIS server polls the Regional Earthquake-Tsunami Monitoring Center at specific time intervals (every 10 seconds) and downloads the latest earthquake data. The data are formatted in the EIS server and are made ready for the application to process. EIS also utilizes the NERIES ELER V3.1 data to show the instrumental intensity and damage maps to the users in the application.

3.1.1 Latest Earthquakes in Turkey

The "Latest Earthquakes" section in EIS lists the latest 50 earthquakes that happened in Turkey, sorted descending according to the occurrence date-time, starting with the date-time the user opens up the application. The list interface is shown in Figure 3.7.



Figure 3.7 Recent earthquakes list.

The user can select the earthquake to get more information about it. When an earthquake is selected, the information about the earthquake is displayed in the application and the epicenter is shown over the Turkey map. The information consists of the name, date, time, depth, geographical location and magnitude of the selected earthquake. Figure 3.8 shows a selected earthquake in detailed map.

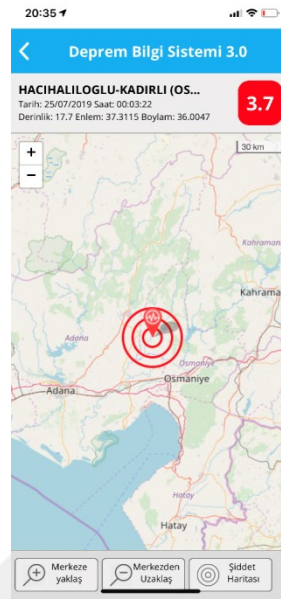


Figure 3.8 Detailed information on selected earthquake.

The user can use the “Merkeze Yaklaş” (Zoom to Epicenter) button to zoom to the epicenter of the earthquake as shown in Figure 3.9. Further zoom can be acquired by using the “pinch” technique over the screen of the mobile device.

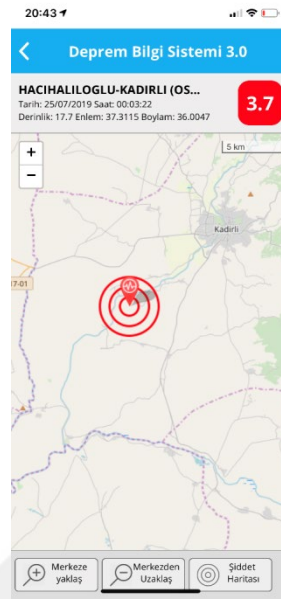


Figure 3.9 Selected earthquake, zoomed-in in the application.

“Merkezden Uzaklaş” (Zoom out) button can be used the zoom out from the epicenter see the location of the earthquake on a larger Turkey map (see Figure 3.10)

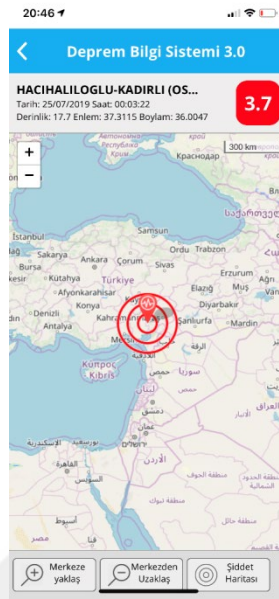


Figure 3.10 Selected earthquake, zoomed-out in the application

The “Şiddet Haritası” (Intensity Map) button can be used to display the ELER instrumental intensity and damage maps over the map to see which areas are affected and how they are affected from the earthquake. The intensity map data specific to the selected earthquake are downloaded from the KOERI server, formatted and displayed over the earthquake map.

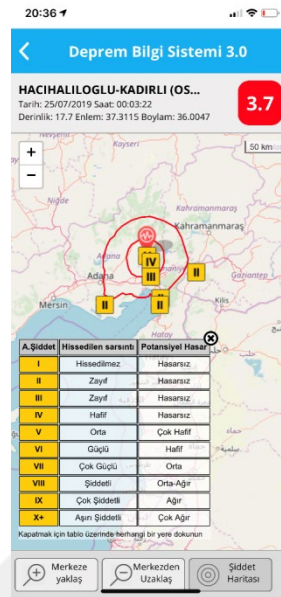


Figure 3.11 ELER instrumental intensity map displayed over the selected earthquake.

3.1.2 Seismic History of Turkey

EIS has another section, which enables users to display the seismic history of each location in Turkey. The data used in this section are provided by KOERI and date back to year 1900. All the recorded earthquakes in this period, with magnitude larger than 4.0 are displayed. In this section, the user can zoom-in or zoom-out to Turkey map and click anywhere to get the information of the earthquakes happened in 100 kilometers radius of the touched geographic location.

The geographic location of the clicked location and the number of earthquakes happened in 100 kilometers radius are displayed in information box over the map. The map contains all the epicenters of the earthquakes as red dots. The color and size of dots change according to the magnitude of the earthquake.

Seismic history map also shows the faults in Turkey. Displayed fault data are simplified from Emre et al. (2018). The user can display or hide the faults using the buttons “Fayları Göster” (Show Faults) and “Fayları Gizle” (Hide Faults) respectively.

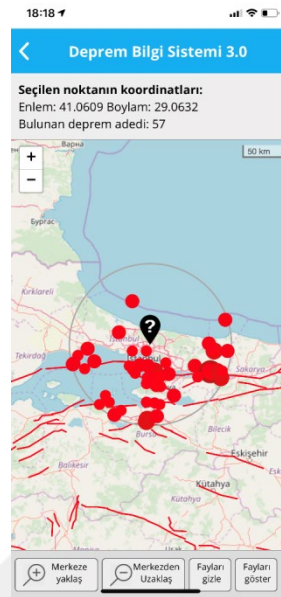


Figure 3.12 Earthquakes happened in 100 kilometers radius of the selected geographical location.

If the user clicks on individual dots, a popup message is displayed containing the date, distance to the selected geographical location and magnitude of the earthquake.

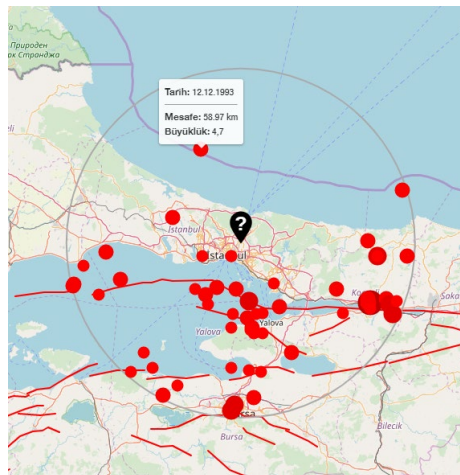


Figure 3.13 Information about the selected historic earthquake.

3.1.3 Seismic History of Current Geographical Location

This section, which can be reached by clicking on “Deprem Geçmiş” (Seismic History) link is very similar to the Seismic History of Turkey discussed in section 3.1.2. The main difference is that, this section immediately takes the geographical location of the mobile user and displays the historic earthquakes around the 100 kilometers radius of his/her location.

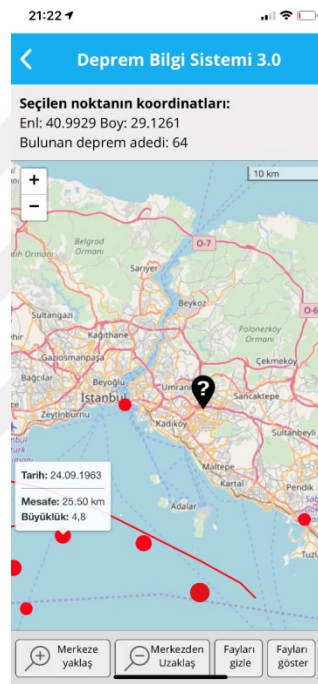


Figure 3.14 Seismic History of Current Geographical Location

3.1.4 Macro-Seismic Survey

The macro-seismic survey is intended to gather data from the users of the mobile application, immediately after they felt an earthquake. When a user feels an earthquake, and if he/she wants to report how he/she felt the earthquake, he/she can click on the link “Deprem Oldu” in the application. At first stage, the user is presented with a list of the last 20 earthquakes happened in Turkey having a magnitude larger than 3.0. This cutoff of 3.0

in magnitude is used to prevent possible false positives (i.e. to prevent the user from clicking on a low magnitude earthquake just because the earthquake name is similar, but which can be an aftershock). After the user selects the earthquake that he/she believes he/she felt, he/she is presented with a series of survey questions. The questions and their contribution to the CII will be discussed in section 3.2 of this thesis.

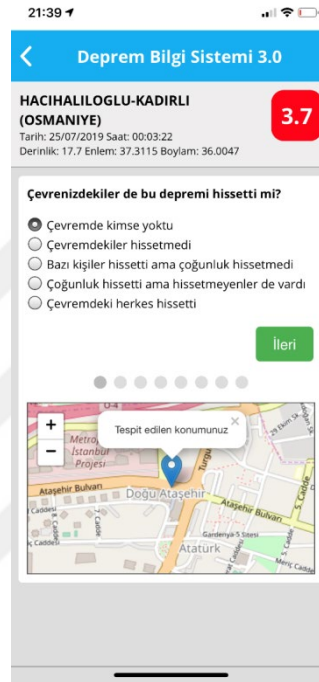


Figure 3.15 Macro seismic survey questions.

In order to the macro-seismic survey to work, the user must allow the application the rights to get the geolocation of the mobile device that is being used. If the application fails to get the geolocation, the survey is not displayed, and the user is warned that he/she should allow the geolocation data to be used by the application.

If the geolocation of the mobile device is determined, then the macro-seismic survey starts. The survey consists of eight sections, each with a different question, aimed to determine the CII of the individual for the specified earthquake. At the end of the survey, the user is thanked for his/her contribution to the project and the central EIS database is updated with the information derived from the survey.

3.2. Questions of the macro-seismic survey

Questions contained in the survey section of the Earthquake Information System have been derived from the works listed as the following (Wald et al, 1999):

1. Did people around you also feel this earthquake?
 - a. There was not anybody around me
 - b. People around me did not feel it
 - c. Some people felt it but majority of them did not
 - d. Majority of the people felt it but some did not
 - e. Everybody around me felt it
2. How would you define the ground shaking?
 - a. Weak
 - b. Mild
 - c. Moderate
 - d. Strong
 - e. Very strong
3. What was your reaction against the earthquake?
 - a. I did not show any reaction
 - b. I felt excited
 - c. I was scared
 - d. I was very scared
 - e. I did not know what to do out of fear
4. Was it difficult to stay standing up or to walk during the earthquake?
 - a. No
 - b. Yes
5. Have articles on the shelves rolled down or fallen off?
 - a. No, they were only shaking
 - b. Few articles rolled down or fell on to the floor
 - c. Most of the articles fell on to the floor
 - d. Everything on the shelves fell on to the floor

6. Did pictures on walls move or fall down?
 - a. No
 - b. Yes, but they did not fall on to the floor
 - c. Yes, some one of them fell on to the floor
7. Did any furniture or appliance move, roll down or was displaced?
 - a. No
 - b. Yes
8. Has any damage taken place inside the building?
 - a. There was no damage
 - b. Fine cracks appeared on the walls
 - c. Few of the glass windows cracked
 - d. Few large cracks appeared on the walls
 - e. A lot of large cracks appeared on the walls
 - f. Lights and ceiling coverings fell down
 - g. Glass windows broke and fell outside
 - h. Bricks fell down from brick walls
 - i. Walls collapsed and rolled down
 - j. Building moved over foundation

3.2.1 Community Internet Intensity

By gathering information from the users who actually experienced an earthquake, researchers can prepare rapid seismic intensity maps for earthquakes and can use this information to further predict the intensities that can be experienced in the future earthquakes in the same region. The result of the surveys can be converted to Community Internet Intensities using a modified algorithm of Dengler and Dewey (1998). Since the purpose of this application is to present information about the felt intensities of earthquakes to the researchers, the data display system programmed in the EIS server contains the calculated CII value for each survey.

To calculate CII, first a weighted sum of the community average values for each question, the "Community Weighted Sum" (CWS) is calculated. Each question is named an index value and each answer in each question have different numerical values. These values are derived based on the algorithm developed by Dengler and Dewey (1998) and applied by Dengler and Dewey (1998) to telephone survey data collected by the Humboldt Earthquake Education Center (HEEC) following the 1994 Northridge earthquake. The questions and index names are presented at Table 3.1. Each question has a numerical value of 0 to nth question that is input to the formula to calculate the CWS.

Table 3.1 Index names for macro-seismic survey questions.

Question #	Index Name
1	"felt" index
2	"motion" index
3	"reaction" index
4	"stand" index
5	"shelf" index
6	"picture" index
7	"furniture" index
8	"damage" index

CWS is calculated according the the formula below:

$$\begin{aligned}
 \text{CWS} = & 5 \times \text{"felt" index (a value from 0 to 1)} \\
 & + \text{"motion" index (a value from 0 to 5)} \\
 & + \text{"reaction" index (0 to 5)} \\
 & + 2 \times \text{"stand" index (a value from 0 to 1)} \\
 & + 5 \times \text{"shelf" index (a value from 0 to 3)} \\
 & + 2 \times \text{"picture" index (a value from 0 to 1)} \\
 & + 3 \times \text{"furniture" index (a value from 0 to 1)} \\
 & + 5 \times \text{"damage" index (a value from 0 to 3)}
 \end{aligned}
 \tag{3.1}$$

Then, the CII is computed as

$$CII = 3.40 \log_e(CWS) - 4.38, \text{ for } CWS \geq 6.53 \quad (3.2)$$

For any "felt" response and $CWS < 6.53$, $CII = 2$; for "not felt" responses, $CII = 1$.

3.2.2 Data display for research

Since the purpose of this thesis and the EIS is to gather information from the users about how they felt the earthquake, a data display module in the backend of the EIS server is also programmed (see Figure 3.11) to display the information gathered from each response to the survey. Data can be aggregated according to the individual earthquake; the database can be searched by using date filters or the last nth responses.





All the geographical locations of the responses to the macro-seismic survey are displayed on map and each user icon can be hovered to display a popup which contains CII value of individual response. Further zoom to the street level of the location of the user can be obtained by clicking on the user icon map.

If the user clicks on an individual earthquake, the data are filtered to show all the survey responses related to that earthquake and the number of respondents, along with the mean CII value are displayed. The ELER instrumental intensity and damage maps are also displayed for the selected earthquake, so a visual comparison with that map and the survey responses can also be done.

The map displaying the survey results can be zoomed, so all the individual responses are clearly visible. Again, when hovered over, all the user icons display a popup showing the CII value for the user.

The icons representing the individual respondents on the map are color coded according to the CII value ranges as shown in Table 3.2.

Table 3.2 Color coded CII values.

CII Range	Icon
$CII < 4$	
$4 < CII < 5$	
$5 < CII < 6$	
$CII > 6$	

All the information gathered from the surveys about the specific earthquake can be exported in CSV format and be further used in other analysis programs to create meaningful results for research purposes. The CSV file contains the geographic location of each respondent (latitude and longitude), the time and date of survey, information about the selected earthquake (geographical coordinates of epicenter, time and date and magnitude).

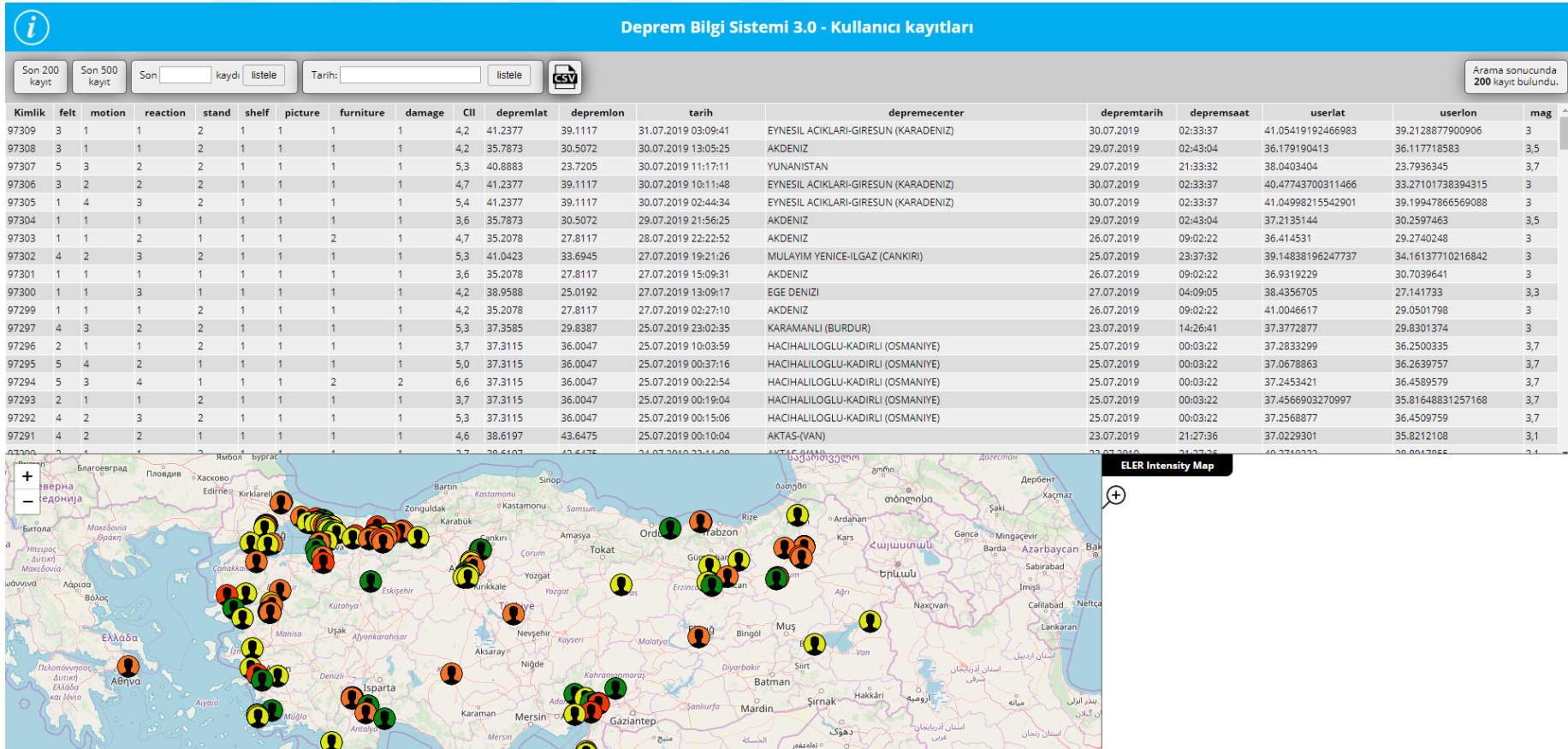


Figure 3.16 EIS data display system, home page

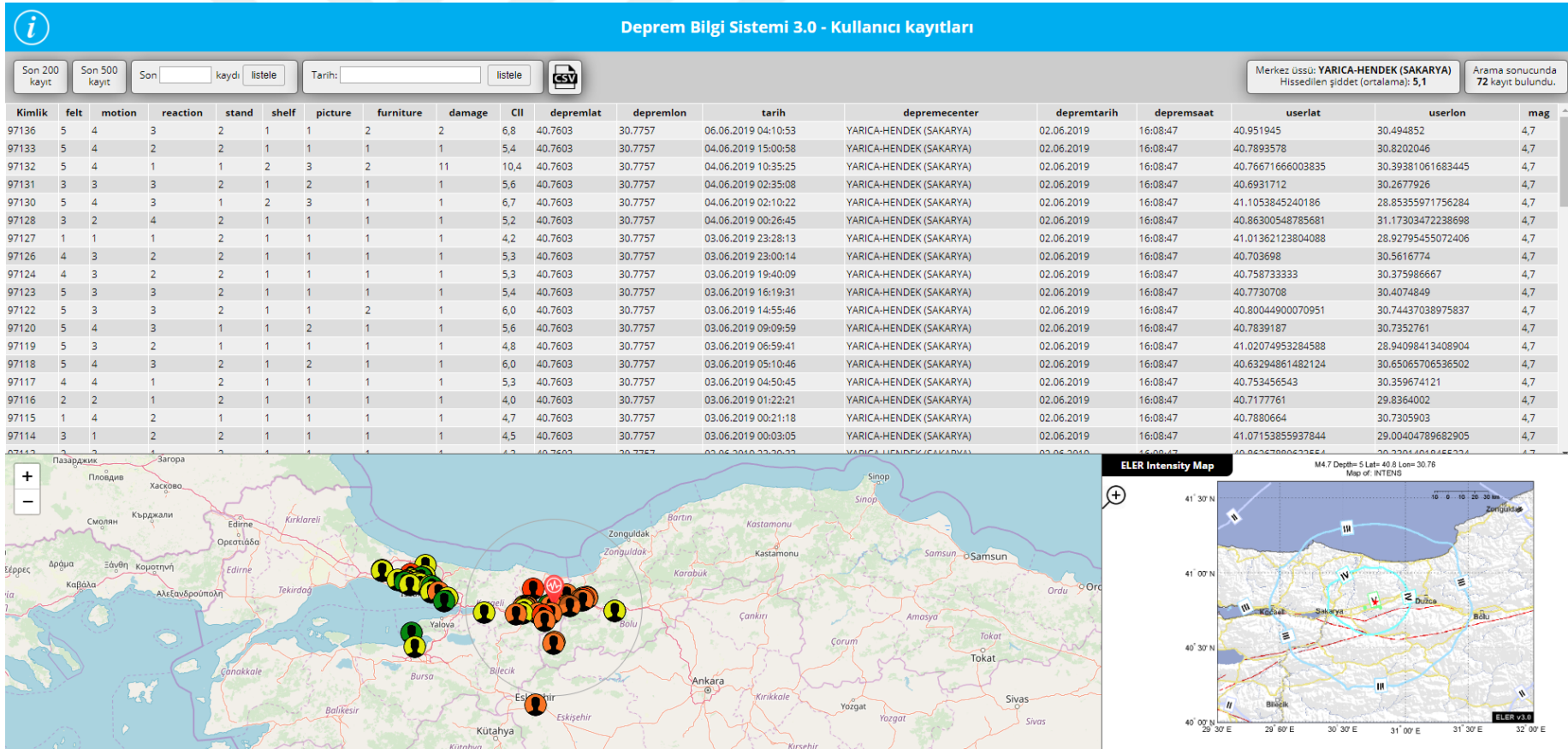


Figure 3.17 EIS data display system, earthquake selected.

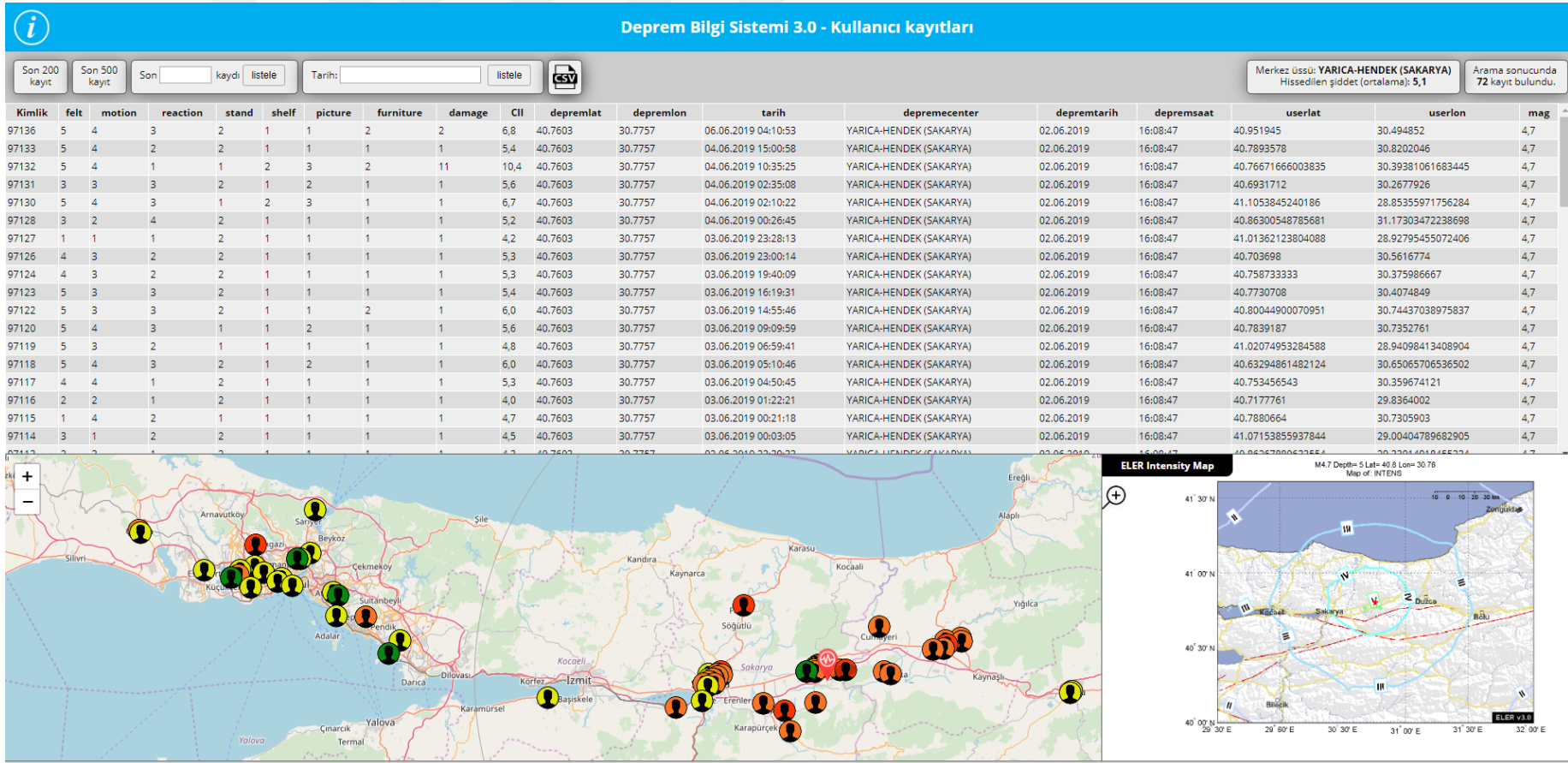


Figure 3.18 EIS data display system, earthquake selected and zoomed.

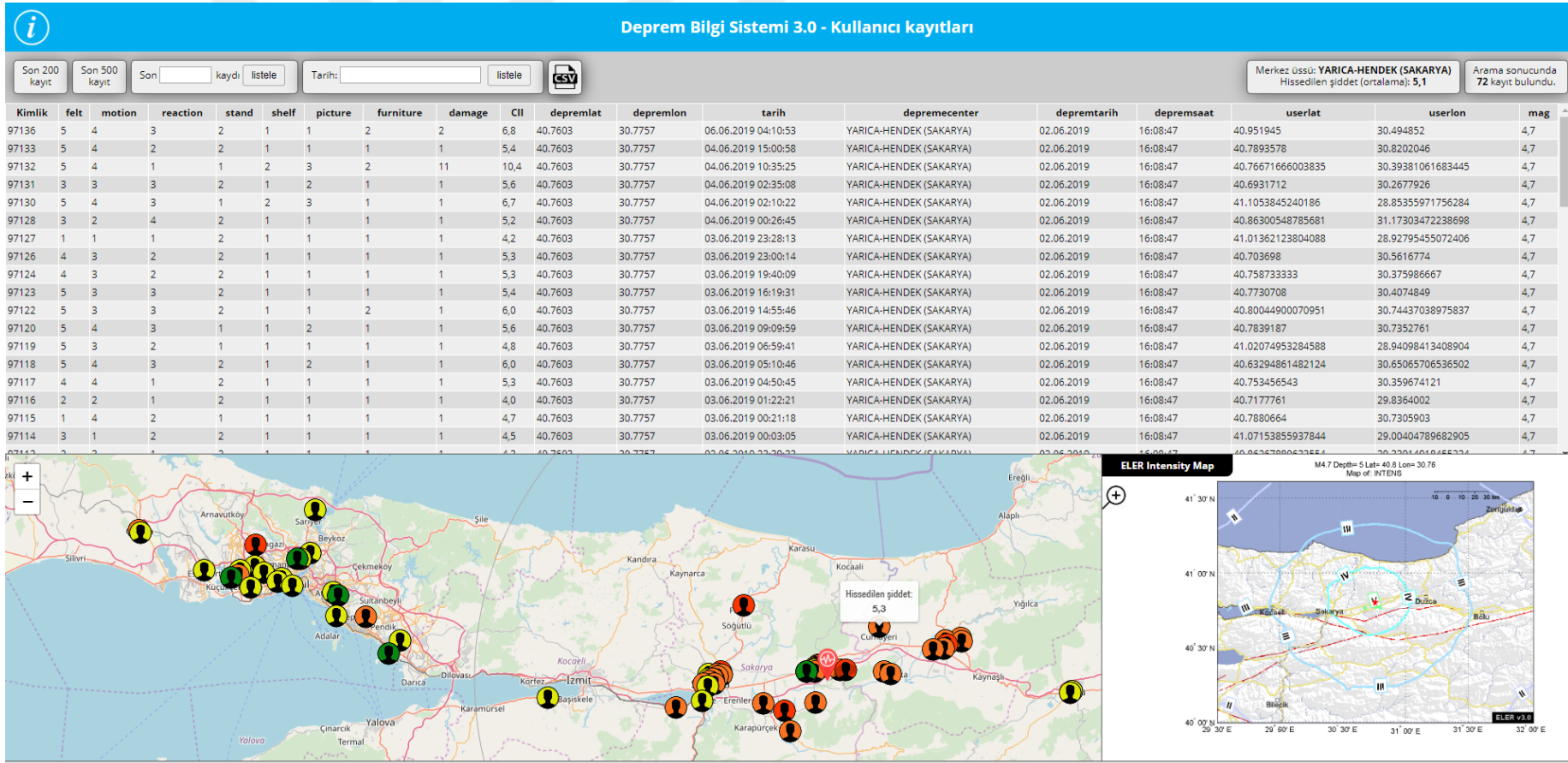


Figure 3.19 EIS data display system, hover over user.

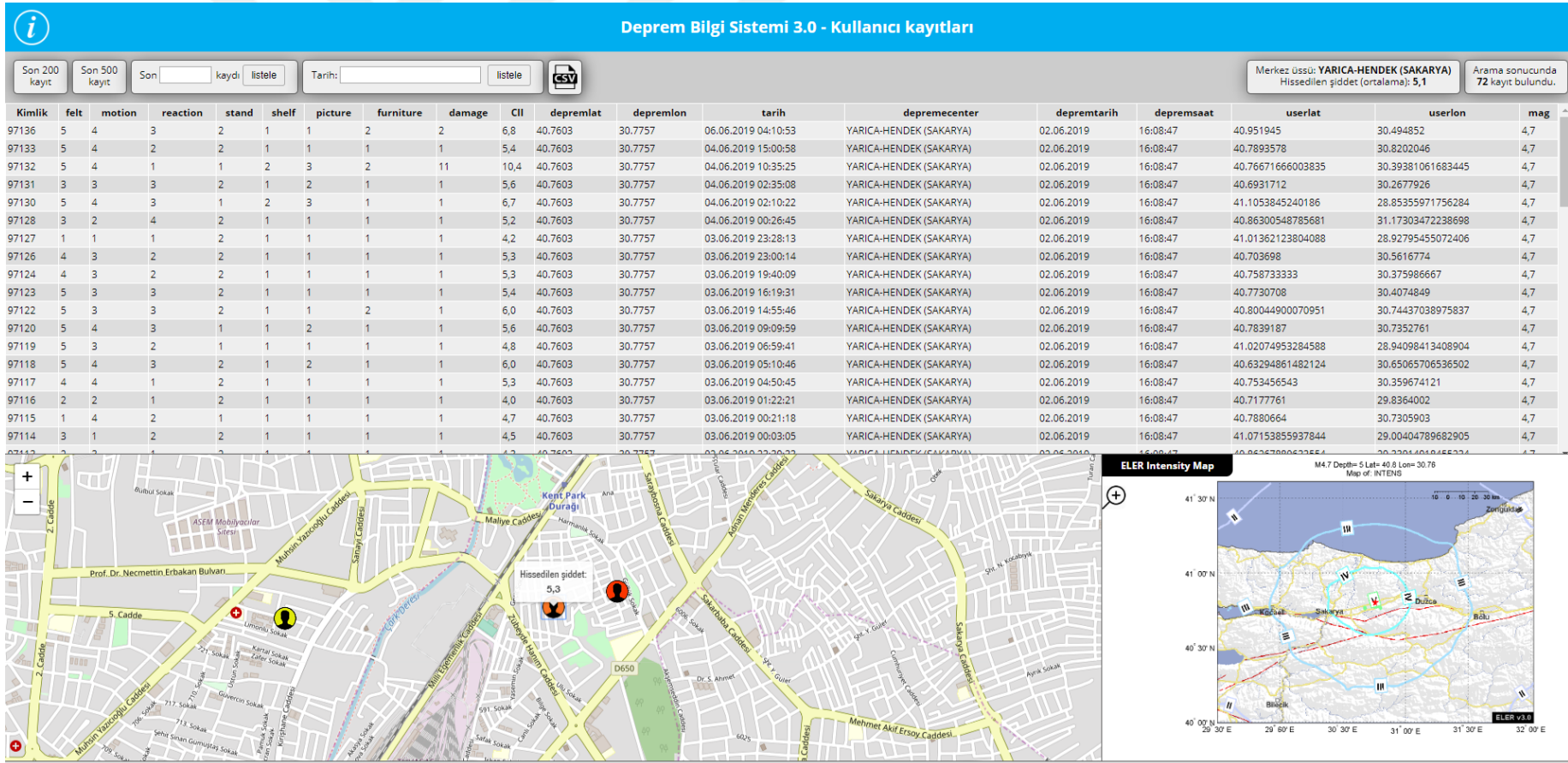


Figure 3.20 EIS data display system, click over user.

4. RESULTS

Table 4.1 shows some of the results of the data obtained from macro-seismic surveys of EIS. EIS database currently hosts about 90,000 records and can be filtered according to date and time of an individual earthquake and all the respondents to this earthquake can be displayed with the Data Display System. An export option is also available for researchers to use this information on different projects and different software platforms.

Table 4.1 Macro-seismic survey, sample results.

Earthquake name	Date	Magnitude	# of respondents	Mean CII	Figure #
GOKOVA KORFEZİ (AKDENİZ)	21.07.2017	6.6	175	5.9	Figure 4.1
BASAKLI-OLTU (ERZURUM)	15.07.2019	4.4	16	5.2	Figure 4.2
YARICA- HENDEK (SAKARYA)	2.06.2019	4.7	72	5.1	Figure 4.3
GOKCEADA	24.05.2014	6.5	200	5.7	Figure 4.4
AKDENİZ	29.12.2013	6.0	200	5.3	Figure 4.5

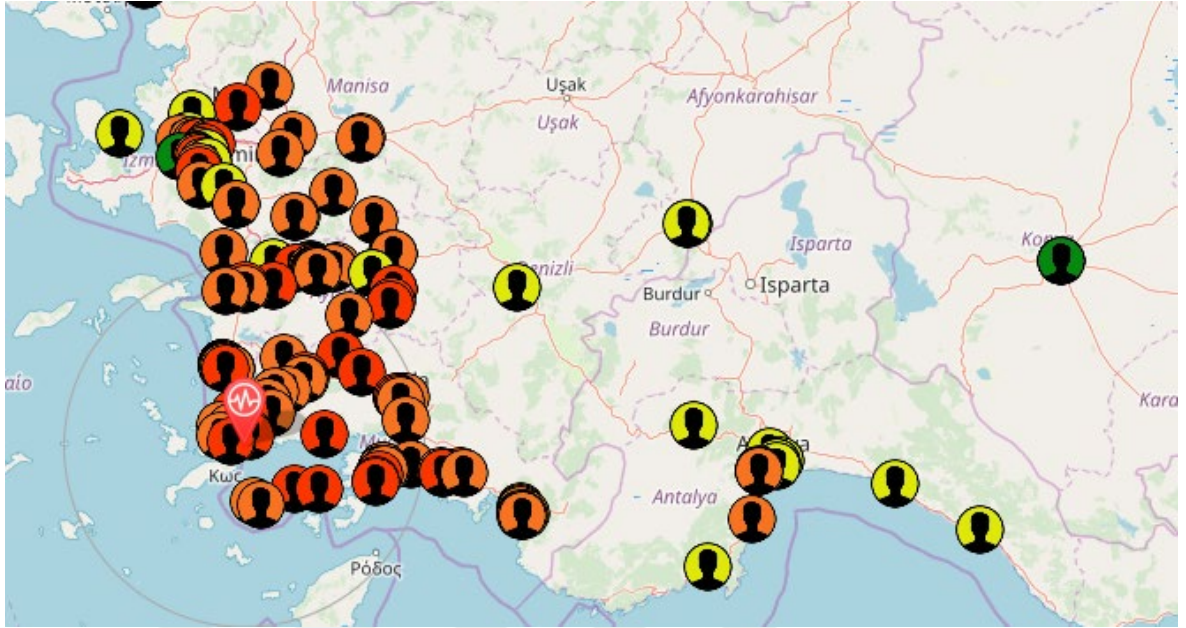


Figure 4.1 GOKOVA KORFEZI (AKDENIZ) earthquake (M6.6) survey respondents.

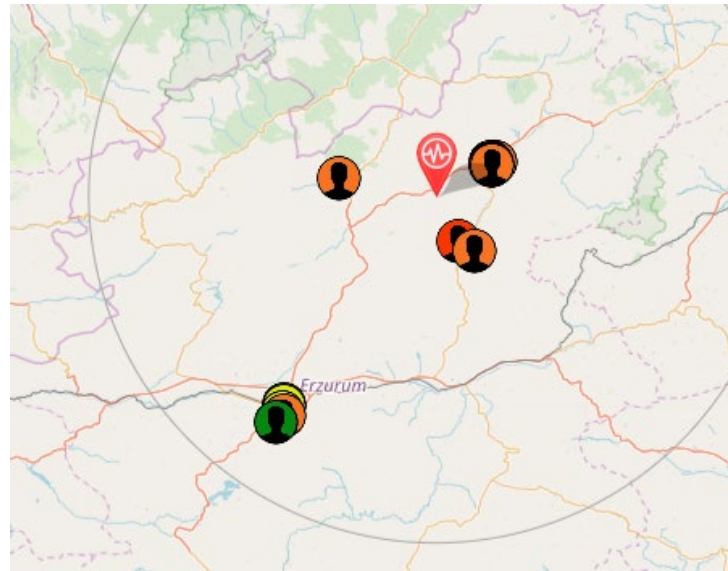


Figure 4.2 BASAKLI-OLTU (ERZURUM) earthquake (M4.4) survey respondents.

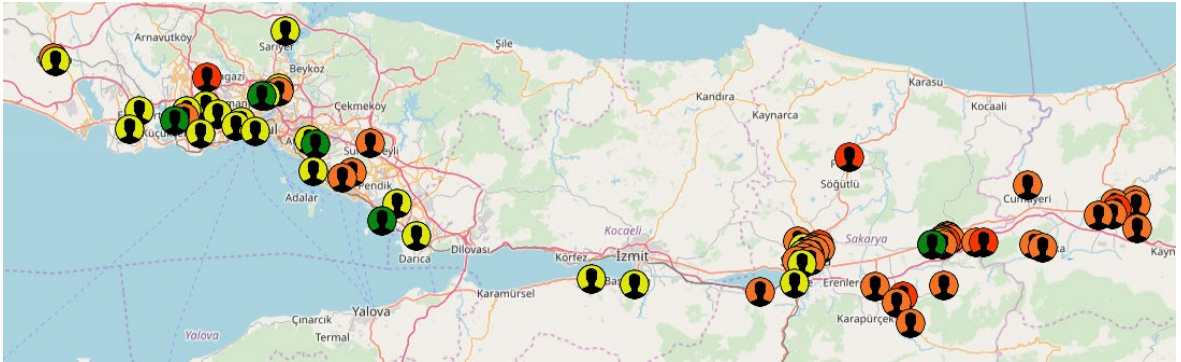


Figure 4.3 YARICA-HENDEK (SAKARYA) earthquake (M5.1) survey respondents.

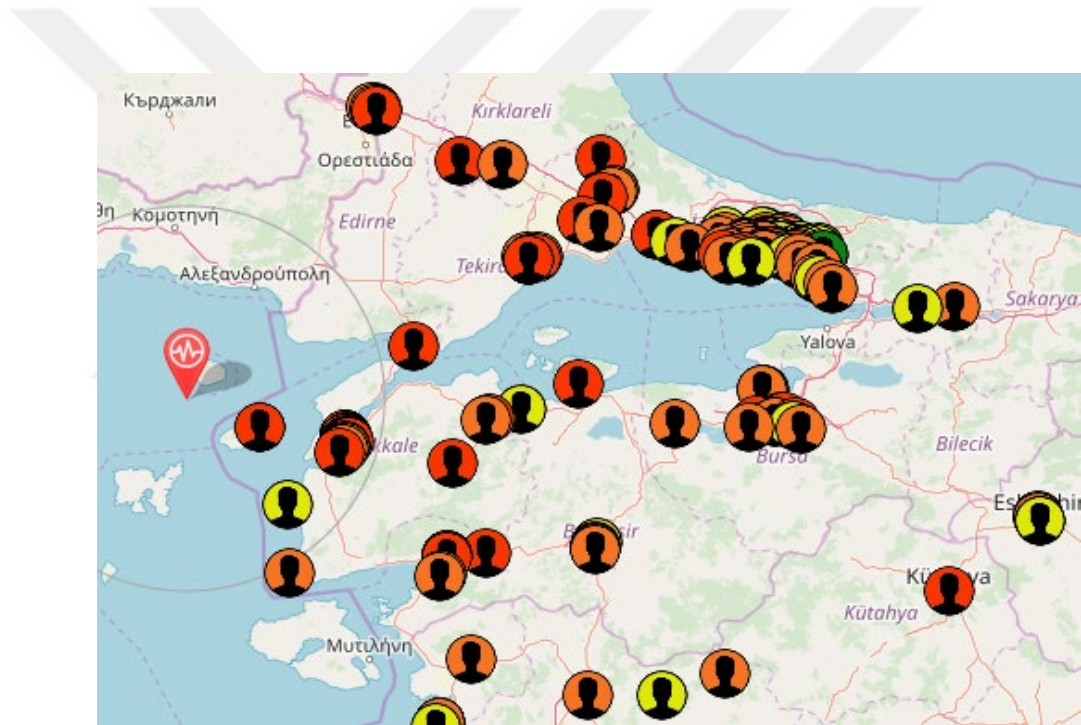


Figure 4.4 GOKCEADA earthquake (M6.5) survey respondents.

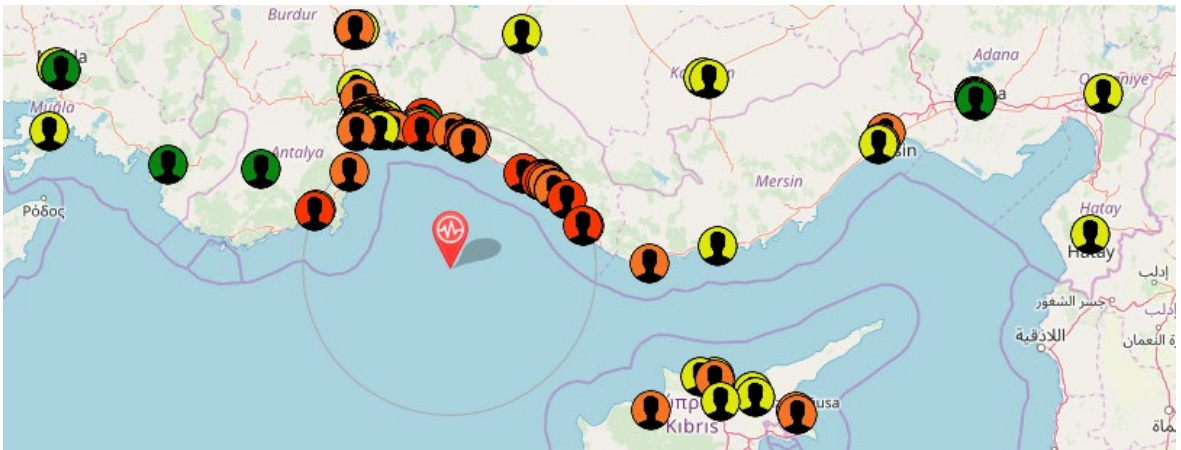


Figure 4.5 AKDENIZ earthquake (M6.0) survey respondents.

Details of the data display interface can be observed at Figure 4.6. Here, when the user hovers over a line in the data grid, the corresponding location icon pops out of the map to show the location of the respondent. In the data grid, one can see the survey answers, CII, coordinates of the respondent at the time when he/she answered the survey, the date – time of the survey and corresponding earthquake information (date-time, coordinates of the epicenter, magnitude). When the user hovers over a respondent icon on the map, the corresponding line on the data grid is highlighted and CII value for that respondent is displayed on the map in a popup.

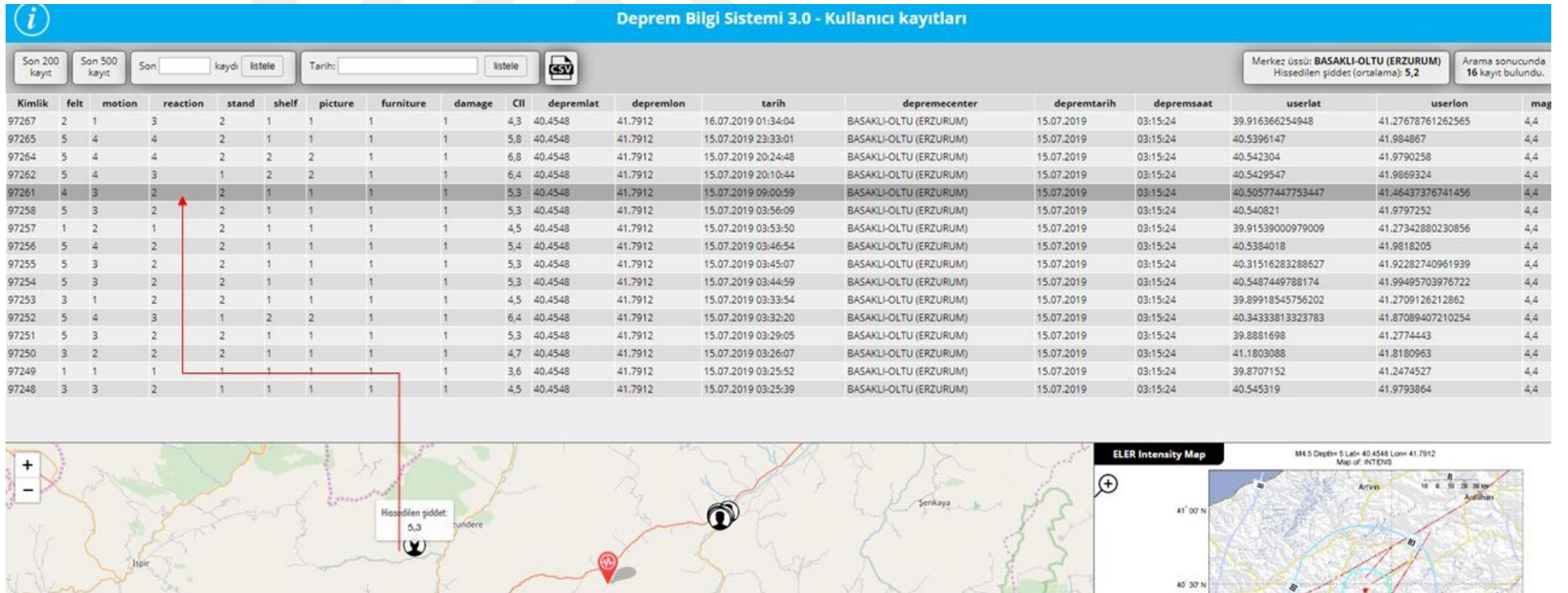


Figure 4.6 Data display interface (respondent selected).

5. CONCLUSION

With the increasing reach of internet and mobile phone usage, it is possible to gather invaluable information from the mobile phones of the users by using simple crowdsourcing methods. These real-life data can be used to fine tune the instrumentally generated intensity and damage maps after an earthquake. Additionally, the historical information gathered after the numerous medium scaled earthquakes can show the nature of the felt intensities at different locations. Using these methods, it may be possible to create models for further, high-risk, high-magnitude earthquakes.

These models can be used to assist the first respondents to the earthquakes by distributing the search and rescue efforts efficiently. One of the purposes of this thesis is to establish a large userbase for the EIS application. Each individual then can be used to gather information and the more the number of respondents to the survey, the more information researchers can obtain from the EIS database. Since the release of the program, 90,000 records are obtained from different locations all over Turkey. These data can be used in different projects to fine tune the intensity and damage maps.

At present, the most recent version of EIS is downloaded and installed by 2,300 Android and 2,500 IOS users. It is imperative that the userbase for this application to expand in order to have the opportunity to gather more data after an earthquake. Crowdsourcing applications rely heavily on having a large userbase. It is suggested that the application is advertised by all means, nation-wide, to create public awareness and increase the number of installations. Online news channels, technology portals, social media channels are some of the options to consider for advertising the EIS application.

Data display system is a flexible front-end for the gathered data and can further be developed to analyze data and create reports immediately after the occurrence of an earthquake. Also, since EIS is a hosted application which resides in EIS servers in KOERI, it can also be developed further, giving more information to the users and gathering more information back.

REFERENCES

Atkinson and Wald (2007), “Did You Feel It?” Intensity Data: A Surprisingly Good Measure of Earthquake Ground Motion”, *Seismological Research Letters*, Vol: 7/3, pp: 362-368.

Coburn, A. and Spence, R. (2002). *Earthquake Protection* (2nd edn), Wiley, Chichester, U.K.

ELER Software Manual, 2013,

http://www.koeri.boun.edu.tr/deprenmmuh/ELER/ELER_v3_Manual.pdf

Emre Ö, Duman TY, Özalp S, Şaroğlu F, Olgun Ş, Elmacı H, Çan T (2016) Active fault database of Turkey. *Bull Earthquake Eng* (2018) 16:3229–3275 doi:10.1007/s10518-016-0041-2

EMSC, (2011), <http://www.emsc.eu/Earthquake/> felt. php.

GEONET, (2011), <http://www.geonet.org.nz>

INGV, (2011), <http://www.haisentitoilterremoto.it>

KOERI, (2013), *Earthquake Information System v1.1*, <http://m.koeri.boun.edu.tr/dbs>

Sbarra, P., P. Tosi and V. De Rubeis , 2010,” Web-based macroseismic survey in Italy: method validation and results”, *Nat. Hazards*, 54, 563-581

USGS, (2013a), <http://earthquake.usgs.gov/research/dyfi/>

USGS, (2013b),

http://earthquake.usgs.gov/earthquakes/shakemap/global/shake/c000fd56/#Instrumental_Intensity

Wald, D.J., Quitoriano, V., Dengler, L. and Dewey, J.W. (1999). Utilization of the Internet for Rapid Community Intensity Maps, *Seismol. Res. Letters*, 70 (6), 680-697.

Wald, D. J., Quitoriano, V., Worden, B., Hopper M., Dewey, J. W., 2011, "USGS "Did You Feel It?" Internet-based macroseismic intensity maps", *Annals of Geophysics*, Vol 54, No 6.

