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Computer aided intensity assessment in Austria

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Abstract - Internet-based macroseismic questionnaires are becoming more and more an alternative for collecting data from the public. Experience in Austria has shown, that questionnaires received via the Internet have already outnumbered questionnaires which arrive by fax and mail. Therefore, a method to evaluate this "new kind" of macroseismic data objectively was developed to speed up the analysis and to provide authorities with almost real-time information in the future. In addition, the method lends itself to cross-border data exchange circumventing the problem of interpreting questionnaires originating from different countries.

1. Introduction

After a magnitude 4.9 earthquake in Ebreichsdorf near Vienna in the early hours of July 11, 2000 the Seismological Service of Austria decided to put a questionnaire on the world wide web to collect responses from the community regarding the observed effects from earthquakes. The feed-back was exciting and several 100 questionnaires - even from remote areas - have been received via the Internet since 2001. Although many responses from the public were not related to an actual earthquake, very valuable, detailed information could be gathered from several tremors, such as an earthquake in South Tyrol on July 17, 2001, from which 230 web-questionnaires were received, although the event did not occur on Austrian territory but in the German-speaking part of Italy. Later that year, on November 21 in 2001, a moderate earthquake with an epicentral intensity of grade 5 occurred near Vienna in Schwadorf, giving rise to 61 responses using web-questionnaires. In 2002, first on January 26 a small earthquake happened near Leoben in Styria (epicentral intensity 4) resulting in 20 returns, and secondly, 213 web-

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questionnaires were collected from the Friuli earthquake on February 14, which resulted in a large spread of local intensities of grade 4 in Austria.

It is not surprising, that the number of questionnaires returned was pretty small since the introduction of the questionnaire on the Internet. Already on the occasion of the earthquake in Ebreichsdorf – which triggered the development of an automatic method for analysing responses – only 0.04% of the population of Vienna responded. It is expected that, once the public becomes more aware of this opportunity, the response will increase and substantially supplement the data set, however.

Therefore, we decided to develop a tool for an automatic evaluation of these data in the future and, at a later stage, to publish the results on the Internet at 30 minute intervals to keep civil protection units and the public informed. The proposed time interval for releasing the results to the public is again based on the experience of the Ebreichsdorf earthquake in 2000, when, right after the earthquake, the first e-mail arrived. During the following hours, over 800 e-mails in individual formats were collected, giving the impression that updates at time intervals of 30 minutes would encourage the public to submit even more descriptions of their observations.

Being aware that similar procedures were already implemented in the United States a few years ago (Wald et al., 1999), a different procedure is proposed here, because the American approach using the Modified Mercalli Scale (MMI) and the Community Weighting Sum (CWS) index does not meet the requirements as stipulated by the European Macroseismic Scale 1998, EMS-98 for short (Grünthal, 1998).

The conversion of the EMS-98 into a formalized procedure turned out to be rather complicated. However, the proposed approach shall not only speed up the evaluation of questionnaires, but shall ease the creation of cross-border intensity grid-maps, which can easily be patched together. In Austria, such situations arise frequently due to the proximity of seismically active areas in Switzerland, Italy, Slovenia and in the Slovak Republic. The proposed method mimics the practice of macroseismic evaluation in Austria only to a certain extent, because an objective treatment of data by analysing the data manually is hampered by expectations and even individual experience.

2. Approach

The first step involves finding a way to categorize “Community Intensities” in terms of “very few”, “few”, “many”, “most”, which are not based on regressions as in the approach by Wald et al. (1999). Instead, the data are treated as strictly as possible according to the EMS-98. In order to address this task, three categories of questionnaire entries regarding “Human perception”, “Objects” and “Damage of buildings” are distinguished, evaluated and grouped according to their coordinates to form a community data set. The coordinates of the place a questionnaire is referring to, are identified by the stated name of the city/village and the postal code. The EMS-98 quantities “few”, “many” and “most” are determined later by evaluating tables, in which all entries are stored according to a special scheme of codes, which will be presented here. The columns of this table represent the quantities, whereas the rows refer to intensities. Finally, the match of each row (intensity) with the standard quantities is determined. The row, with the best match – or smallest deviation – indicates the desired "Community Intensity"' of a specific data set (bin).

The second step involves a procedure, which allows us to map the data automatically for rapid transmission to the public. This approach will enable cross-border patching of national evaluated data sets, thus avoiding problems with exchanging intensity data based on different questionnaires and evaluation practices. If all e-mail entries are treated as the EMS-98 is, problems due to different practices should not arise anymore once the proposed algorithm has been adopted, and the grid-map format presented should fit into other grid-maps from neighbouring countries, thus permitting a display of regional intensities - even across borders - in almost real-time. This is important, because Austria is surrounded by countries which use different questionnaires, according to their own tradition of evaluating macroseismic data. These questionnaires cannot be directly included by simply exchanging them, since several languages are used (Hungarian, Italian, Slovak, Slovenian) and place names are referred to differently in these languages, resulting in additional work when trying to keep up-to-date with possible changes of postal codes in the neighbouring countries and multiple place names near the borders of the countries, including special characters which are used only in one of the languages.

3. Principle

All three categories (effects regarding human perception, objects, and damage to buildings) are evaluated for each "bin", that is the region, from which the questionnaires have been returned or are referring to. The size of the bin depends on the population density, and will be discussed later.

First, the result of each category is treated separately, later on these three categories are summed. This procedure also permits the introduction of weighting factors for the three categories. The latter is formally not part of the EMS-98, but might be useful at a later stage,

Table 1 - Table for "Human Perception". The respective "codes" for the observed effects are listed to the right.

EMS-98	Very few (< 1%)	Few (1% - < 20%)	Many (20% - 60%)	Most (> 60%)
1	-	-	-	-
2	R, T	-	-	R*
3	-	S, T	R	
4	W	U	S	
5	-	W, X	U	S, V
6	-	Y	W, X	S
7	-	-	Y, Z	W,X
8	-	-	Z	-
9	-	-	-	Z
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-

Position in Matrix	Legend
R, R*	Felt at rest
S	Indoors
T	Slight trembling
U	Awake
V	Strong trembling
W	Outdoors
X	Frightening
Y	Balance, upper floors
Z	Balance

* only in upper floors

once enough experience with Internet-questionnaires has been gained. Setting two of the weighting factors, referring to specific categories (e.g. “Objects” and “Damage to buildings”), to zero allows us to check whether the entries in the category of “Human perception” alone would indicate the correct intensity degree. The same approach can be used to verify the validity of the intensity assessment for the other two categories.

The basic principle involves the evaluation of each returned questionnaire. Reported effects are allocated to a “code” (Table 1, right side), which defines a specific position in the table (matrix, Table 1, left side). First, all cells are set to zero for this particular earthquake. If a questionnaire reflects a certain observed effect, it is allocated to a code. Then, we add a, “1” to the respective cell according to the code in the table (see Tables 1 and 2 and basically Table 4).

Since each effect might be confirmed several times in a questionnaire, we allow that a particular cell may assume only a value of “1” (= yes, confirmed) or “0” (= no, does not apply). The computer program continues with the remaining questionnaires and proceeding the same way by adding “0” or “1” to each appropriate cell. Alternatively, separate tables can be set up for each questionnaire and added up at the end, to form a single table. The position of the code in the table (Table 1, left side) reflects where “few”, “many” and “most” entries are to be expected. Naturally, this is unknown when completing the table. Only at the end, and after all questionnaires were processed could one calculate the actual percentage in each cell, thus allowing us to determine which row (= intensity) meets the required quantities best.

Hence, after all questionnaires from a particular region have been evaluated, the numbers in the cells are divided by the total number of considered questionnaires (N). Finally, the deviations from the mean values of standard quantities within each category are calculated, weighted and added up for each row, and re-scaled. The row with the smallest deviation, or highest re-scaled value, indicates the desired “Community Intensity”.

Table 2 - Objects.

EMS-98	Few (< 20%)	Many (20%)
1	-	-
2	-	-
3	-	H
4	J	I
5	L	K
6	N	M
7	-	O
8	-	P
9	-	-
10	-	-
11	-	-
12	-	-

Position in Matrix	Legend
H	Hanging objects swing slightly
I	Hanging objects swing, glasses, windows & doors rattle, light furniture shakes visibly
J	Light furniture, woodwork creaks
K	Hanging objects swing considerably, glasses clatter, windows & doors open and shut, light top-heavy objects shift or fall, animals indoors become uneasy, liquids oscillate and may spill
L	Window panes break
M	Small objects fall and furniture may be shifted, farm animals may be frightened
N	Dishes and glassware may break
O	Furniture is shifted, top-heavy furniture may be overturned, objects fall from shelves, water splashes from containers, tanks and pools
P	Furniture may be overturned, heavy objects (TV sets, typewriters) fall down

In Table 1, the codes and percentages, according to the EMS-98, were already shown for the first category, namely "Human perception". The same procedure was then applied to the tables of "Objects" (Table 2) and "Damage to buildings" (Tables 3 and 4).

Before one is able to determine the intensity from damage reports, it is necessary to assign a vulnerability class to each building according to the description given in the questionnaire.
Four building categories (Table 3) are addressed in Austria's questionnaire:

1. rubble stone, fieldstone, adobe;
2. masonry in a broad sense;
3. RC structures;
4. timber structures.

Based on the condition of the building - a parameter which is asked for in the national questionnaire – a vulnerability class ranging from "A" to "E" (see EMS-98) is allocated. If no specific information is given in the questionnaire, the vulnerability class "C" has been chosen as default in Austria, as most masonry buildings are built of massive stones or are not reinforced but equipped with reinforced concrete floors. Class 'F' has been omitted in the case of Austria because reinforced concrete structures are not designed with a high level of earthquake resistance and virtually no pure steel structures do exist.

Table 3 - Vulnerability.

	⇦ **Building Category** ⇨			
Condition	1	2	3	4
Above average*	B	C	E	E
Good	A	B	D	D
Bad	A	A	C	C

Note: 'Above average*' in Fig. 3 refers to buildings, which have been statically improved or adhere to the most recent building code.

First, we have to count the cases in each damage grade/vulnerability class and express them in percentages.

These percentages will later be placed in the intensity/damage table (Table 4) according to the scenario-key positions resulting from the vulnerability class of the involved building

Table 4 - Damage.

EMS-98	**Few (< 20%)**	**Many (20% - 60%)**	**Most (> 60%)**
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	A1, B1	-	-
6	A2, B2, C1	A1, B1	-
7	A4, B3, C2, D1	A3, B2	-
8	A5, B4, C3, D2	A4, B3, C2	-
9	B5, C4, D3, E2	A5, B4, C3, D2	-
10	C5, D4, E3, F2	B5, C4, D3, E2	A5
11	D5, E4, F3	C5, D4, E3, F2	B5, C4, D3
12	-	-	A5, B5, C5, D5, E5, F5

categories in Table 3. At this point, we face a problem with assessing the quantity of buildings of each vulnerability class which was not damaged. In many of the returned questionnaires no building type was mentioned up to now. In our case, we plan to take the sum of all returned questionnaires from a particular region, subtract the number of all questionnaires stating damage, and split the rest the involved categories evenly, but a more sophisticated approach is needed here.

For each vulnerability class and damage grade a "1" is added in the specific cell in Table 4 (e.g. vulnerability class B and damage 2 is labelled as B2, which indicates the appropriate cell position).

4. Determining the most appropriate "Community Intensity"

Having all three tables (Tables 1, 2 and 4) completed, the quality of fit is determined from the deviations in each intensity-row according to its percentage. We have to note, that each category - "Human perception", "Objects" and "Damage to buildings" - deals with different quantity classes. This is taken care of by introducing three formulas in which the quantities *VeryFew*, *Few*, *Most* and *Many*, as well as *ManyMost* need to be entered as percentages. The following approach is certainly only one of many possible ways of determining the most appropriate intensity grade.

Human perception

$$\text{deviation} = \frac{W_1}{k_0}\left(k_1\frac{|VeryFew - 0.5|}{0.5} + k_2\frac{|Few - 10.5|}{9.5} + k_3\frac{|Many - 40|}{20} + k_4\frac{|Most - 80|}{20} + k_5\right)$$

Objects

$$\text{deviation} = \frac{W_2}{k_0}\left(k_1\frac{|Few - 10|}{10} + k_2\frac{|ManyMost - 60|}{40} + k_3\right)$$

Damage to buildings

$$\text{deviation} = \frac{W_3}{k_0}\left(k_1\frac{|Few - 10|}{10} + k_2\frac{|Many - 40|}{20} + k_3\frac{|Most - 80|}{20} + k_4\right)$$

Each centre-value of each quantity-category (e.g. 10.5% for the category *Few* for "Human perception") and its corresponding half-width (e.g. 9.5) form part of this calculation. For reasons of clarity, the weighting factors W_1, W_2 and W_3 have been set to 1 in the following example. All constants, which are needed to calculate the deviation from standard quantities (EMS-98) are given in Table 5. They take care of the number of qualifying cell positions and ease computation for only three formulas need to be considered, covering all intensity classes.

Table 5 - Constants for calculating the best match, based on required quantities.

EMS-98	Human Perception						Objects				Damage				
	k_0	k_1	k_2	k_3	k_4	k_5	k_0	k_1	k_2	k_3	k_0	k_1	k_2	k_3	k_4
1	1	0	0	0	0	1	1	0	0	1	1	0	0	0	1
2	5	1	0	0	1	0	1	0	0	1	1	0	0	0	1
3	7.10526	0	1	1	1	0	1.5	0	1	0	1	0	0	0	1
4	8.10526	1	1	1	1	0	2.5	1	1	0	1	0	0	0	1
5	7.10526	0	1	1	1	0	2.5	1	1	0	1	1	0	0	0
6	7.10526	0	1	1	1	0	2.5	1	1	0	3	1	1	0	0
7	6	0	0	1	1	0	1.5	0	1	0	3	1	1	0	0
8	2	0	0	1	0	0	1.5	0	1	0	3	1	1	0	0
9	4	0	0	0	1	0	1	0	0	1	3	1	1	0	0
10	1	0	0	0	0	1	1	0	0	1	7	1	1	1	0
11	1	0	0	0	0	1	1	0	0	1	7	1	1	1	0
12	1	0	0	0	0	1	1	0	0	1	4	0	0	1	0

Finally, we re-scale the deviations to end up with a reasonable graph. Re-scaling is carried out by calculating the difference between the actual sum of deviations in each row from those of intensity 1 which is then divided by the difference between the smallest deviation and those of intensity 1. This approach flips the graph, and the row (intensity) with the smallest value (smallest deviation) is allocated a value of 1, whereas all other rows with larger deviations end up with values smaller than 1.

5. Example

The questionnaires from a specific region, reporting an earthquake, close to midnight (this is important, otherwise little information would be gained in terms of people 'woken up'), give the following impression (total returns: 100):

1. Human perception: Felt indoors by 90 (S = 90), 40 woken up (U = 40), 10 felt it outdoors (W = 10), 20 were running outdoors (W = 20, but X = 20 and not W, because "running outdoors" actually means "frightened"), 10 said they were frightened (X = 10) of which 5 were not only frightened but also ran outdoors (W = 5). Hence, W_{max} = 10 and X_{max} = 20.
2. Objects: 50 reported lamps swinging considerably, 45 cases of clattering glasses were reported, in 5 cases animals indoors became uneasy, small objects fell in 40 cases. All of which qualify within the effect defined by code K, hence K_{max} = 50.
3. Damage to buildings (vulnerability class, damage grade): Five cases vulnerability class A with damage 1 (cell position A1), five cases reported damage grade 1 to B-type buildings. Hence, 90 buildings remained undamaged, or 45 buildings of vulnerability class A and 45 buildings of vulnerability class B. That means, that the total number of A-buildings, as well as those from B-buildings equals 50. Here, we face the problem of defining the spread of building classes within a specific region, which emphasizes the need to assess the frequency distribution of building classes on a regional basis. An additional problem could be several reports from one and the same building which can only be handled by comparing the addresses. Such a case has not been observed during the past two years, however.

Table 6 - All three tables with their corresponding deviations. Boxed cells reflect quantities and their relation to intensities of the EMS-98.

	Human perception					Objects			Damage to buildings					
EMS-98	very few (< 1%)	few (1%-20%)	many (20%-60%)	most (> 60%)	dev.	few (< 20%)	most/many (> 20%)	dev.	few (< 20%)	many (20%-60%)	most (> 60%)	dev.	sum of dev.	re-scaled
1	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
2	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
3	0%	90%	0%	0%	2.02	0%	0%	1.00	0%	0%	0%	1.00	4.02	-0.51
4	10%	0%	90%	0%	3.28	0%	0%	1.00	0%	0%	0%	1.00	5.28	-1.14
5	0%	20%	0%	90%	0.49	0%	50%	0.50	10%	0%	0%	0.00	0.99	1.00
6	0%	0%	20%	90%	0.37	0%	0%	1.00	0%	10%	0%	0.83	2.20	0.40
7	0%	0%	0%	20%	0.83	0%	0%	1.00	0%	0%	0%	1.00	2.83	0.08
8	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
9	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
10	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
11	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00
12	0%	0%	0%	0%	1.00	0%	0%	1.00	0%	0%	0%	1.00	3.00	0.00

Adding up the three deviations, from each group ("Human perception", "Objects", "Damage to buildings", see Table 6) in each row, and re-scaling it, leads to the most likely "Community Intensity", in this case a degree of intensity of "5" (Fig. 1).

Setting one or two of the weights (W_1, W_2, W_3) to zero, one gains an impression of the effect on the intensity-assignments based on reports referring to combinations of specific categories or a single category ("Human perception", "Objects" or "Damage to buildings") only.

6. General remarks

- Human perception: Often no difference in the matrix positions between "running outdoors", "felt outdoors" (both scenario "*W*") and "frightening" (scenario "*X*") can be observed. In such a case, the maximum of either "*W*" or "*X*" is entered into the matrix, if both occupy the same cell. This applies to other cell positions too, such as "Felt at rest" and "Slight trembling", or "Awake" and "Slight trembling", and so on.
- Objects: The observation of objects is restricted to intensity degrees ranging from 3 to 8 according to the EMS-98. Obviously, all hanging objects would also swing above intensity 5, and standing objects would topple at intensities beyond degree 8. The observation of objects clearly dominates the end result in the mid-range of intensities, if no weighting has been introduced. Observations from objects merely already reflect the intensity directly. Understandably no indications can be stated in the EMS-98 on how many of the total of objects fell, etc.
- Damage to buildings: Most people do not know the condition of their building, thus cannot report it, or they give irrelevant answers. In such a case, vulnerability class "C" is assumed in Austria.

Each type of building was allocated its main vulnerability class. Since almost all building classes encompass a vulnerability level below and above – or even two classes below their

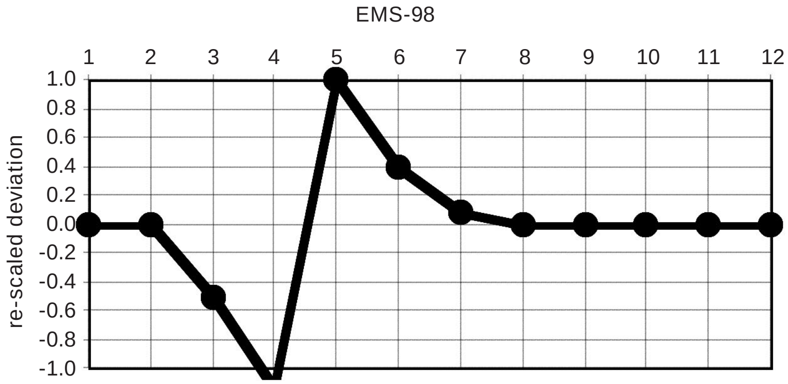

Fig. 1 - Graphical representation of the re-scaled sum of deviations, indicating the most appropriate "Community Intensity" of a specific bin.

average – care must be taken, and an on-site inspections should be carried out, if specialized personnel is at hand.

In the proposal presented, the damage to buildings is evaluated according to the building standard in Austria. The table, linking building conditions to the quality of the building (Table 3), might need to be altered when used in other countries, and regional-dependent frequency-distributions of vulnerability classes should be considered.

- Should there be only reports from high-rise buildings (above the 5^{th} storey level, R* applies in Fig. 1) available from a bin, a "Community Intensity" of 2 is allocated.
- Should two intensity rows show 'similar' re-scaled deviations, the intensity should be e.g. "5-6", for it cannot be decided, whether degree "5" or "6" is more appropriate. As a "similar" proposal could mean, that the ratio of the two dominating categories does not differ by more than a factor of 2/3.
- The method lends itself to studing variations in quantities and their effect on intensity assignments. This becomes apparent, when looking at the category "most" in the "building-damage" table. Completing the column down to intensity grade 7 (with e.g. A2, B1, and for intensity grade 8 with A3, B2, C1 and so on), would alter the intensity assignments drastically. In particular, many intensity - 7 cases would then turn into intensity - 8 cases, because the quantity 'most' is addressed in the EMS-98 beyond intensity 9 only. To adhere strictly to the EMS-98, we decided to omit this possibility, however.
- Effects in nature are discarded in the whole process, but kept in the database and the seismologist is informed once such a message has been received via the questionnaire.
- The seismologist should be able to access the database at any time to correct/complete the questionnaires, while documenting why this has been done. Thereafter, the representing intensity of the "bin" (data set) is re-calculated. This applies mainly to non-identified locations due to wrong ZIP-codes or spelling mistakes of the name of the city/village.
- The method presented is extremely robust, even in cases, when a group of people responds with fake/erratic answers on purpose. Such messages may cause a "noise" in the "quantity-spectra" (the final table to be used for re-scaling), which can simply be controlled and (automatically) dealt with by setting a threshold.

7. Defining the bin-size and generating a cross-border map

For generating a map and calculating "Internet Community Intensities" based on a specific region, the bin-size (the geographical area from which questionnaires are considered) must first be determined. The bin size considered in Austria is derived from the area of Austria divided by the number of postal-districts = 83,000 km / 2500 postal districts = 33 km, which equals an almost square-shaped region (bin) with dimensions of an approx. 5 km × 6 km grid or a 1/12 degree of longitude times 1/20 degree of latitude. This approach allows even the capital of Austria, Vienna, to be divided into at least 10 geographical square-shaped districts, or bins (data sets).

Each bin has unique central coordinates and a certain bin-size. This data set (header: date, time, X-grid spacing, Y-grid spacing; followed by X, Y, community intensity) can easily be exchanged later with other agencies via e-mail, or even better via an automatic data request manager like "AutoDRM".

It should be considered, that if the longitude/latitude grid is sub-divided by even integers (like in this example), cross-border patching becomes possible and macroseismic maps could be easily produced in real-time, covering areas exceeding national borders, once the same procedure for evaluating the questionnaires is adopted by neighbouring countries. Higher or lesser resolutions (depending on the population density) can be achieved by simply dividing or multiplying the grid spacing by a factor of 2.

8. Summary

Internet responses have surpassed reports received by postal services and phone calls regarding earthquakes in Austria. The aim of this work is to ease the use of the EMS-98 in the sense as stipulated on page 13 of the EMS-98 (Grünthal, 1998) regarding computerised evaluation, including strict assignments of percentages regarding the quantities *VeryFew*, *Few*, *Many* and *Most*. Three categories were distinguished:

1. "Human perception" scenarios;
2. "Object" scenarios;
3. "Damage to buildings" scenarios.

These scenarios were not mixed, but treated separately as they constitute complete different kinds of observations. Only at the end of the evaluation procedure of a data-collective, deviations from standard quantities are determined, added up, optionally weighted, re-scaled and a "Community Intensity" is allocated to a grid point representing the data-collective.

Another advantage of this approach is the unified, rapid and objective evaluation procedure which can also be used for manually carried out macroseismic assessments. In addition, it provides the means of investigating the robustness of the macroseismic scale. To patch intensity-grid maps together, across political borders, in almost real-time represents an additional advantage once a format for exchanging these maps has been agreed upon. This data exchange format can be as simple as just stating grid(bin)-size, centre of bin and respective intensity as determined by the reporting agency. This approach is extremely important in a small country like Austria, where stronger earthquakes are generally felt across borders in countries which use different questionnaires and languages.

Although the approach presented appears complicated at first sight, it is relatively easy to compute by setting pointers to the appropriate cells of the tables in a database thus assessing the “Community Intensity” most objectively and fast.

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References

Grünthal G. (ed); 1998: *European Macroseismic Scale 1998.* Conseil de l’Europe, Cahiers du Centre Européen de Géodynamique et de Séismologie, Luxembourg, Volume 15, 99 pp.

Wald D.J., Quitoriano V., Dengler L.A. and Dewey J.W.; 1999: *Utilization of the Internet for rapid community intensity maps.* Seis. Res. Let., **70**, 680-697.