Neural network for seismic shaking intensity modeling

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The seismic zonation realizes one of major economic but most complicated tasks of seismology — numerical estimation (assessment) of seismic hazard (on the patch of earth surface), actually performing the prediction of shaking intensity distribution, using ill-found observations and conceptual regulations. The discussed approach to the problem is an attempt of filling the methodological gaps of this prediction by means of networks of artificial neurons — a powerful instrument of statistical analysis, allowing to build the behavior model of shaking intensity, using the limited set of observed examples of this behavior.

A neural-net model was formed on multi-layer, feedforward, fullconnected, controlled neuron network, using for training the error back propagation method and the set of parameter vectors — accessible to us geological, physical and morphological properties of seismic waves propagation medium. For the target the macroseismic estimation of shaking intensity was used.

A highest seismic hazard is threatening Ukraine from the Romanian earthquakes of Vrancea zone. "Domestic" sources do not represent a serious danger, except, possibly, the Crimea, where 1927 event and specificity of region make it a target of zonation.

Vrancea source. The seismic waves propagation media may be regarded as a filter, distorting the wave field, and the projection of elements of this media on an Earth's surface as a digital image or raster, which is shown on Fig. 1.

Every element, or pixel, is described by the vector of parameters, which components are the number of accessible to us descriptions of physical properties of geological media, functionally related to the response of this media on excitation by seismic waves. Factors that govern the seismic field distortion and control a diversity of shaking intensity distributions over the Earth's surface can conditionally be divided into three groups: regional or deep, local, and shallow (Tab. 1).

Table 1. Components of training set for the model of intensity of Ukraine

Parameters	Units	Range
Gravity	10^{-5} m/s^2	–95.4—111.0
Magnetic intensity	10^2 nT	–3.91—11.0
Heath flow	W/m^2	20.0—90.0
Apparent resistance	om	1.5—3712.0
Neotectonic movment amplitude	m	–3904.0—2084.0
Modern movements velocity	mm/year	–5.10—4.64
Basement depth	km	0—16.0
Fault density	n/pixel	0—4
Horizontal relief section	km/km^2	0.16—2.46
Vertical relief section	m	4.3—413.0
Hypocentral distance	km	230.8—1492.9
Back azimuth	Degree	171.3—330.6
Magnitude	Richter	6.7—7.2
Source depth	km	90—120
Shaking intensity	MSK-64	2.5—7.0

A near zone, that envelopes the southwest of the country, is exposed to body waves, macroseismic effect of which is controlled to a considerable degree by the local inhomogeneties and source mechanism. Shaking intensity in a distant zone is governed by the surface waves, for which defining are regional features of geological structure functionally related to integral characteristics of the stationary physical fields. Macroseismic measurements in metric of MSK-type scale are based on the reactions of standard sensors, which are largely determined by character of coupling with the Earth's surface. The mediated characteristic of such a contact can serve for the level assessment of its degeneration under influence of endogenous and exogenous factors, determined by the horizontal and vertical relief sections.

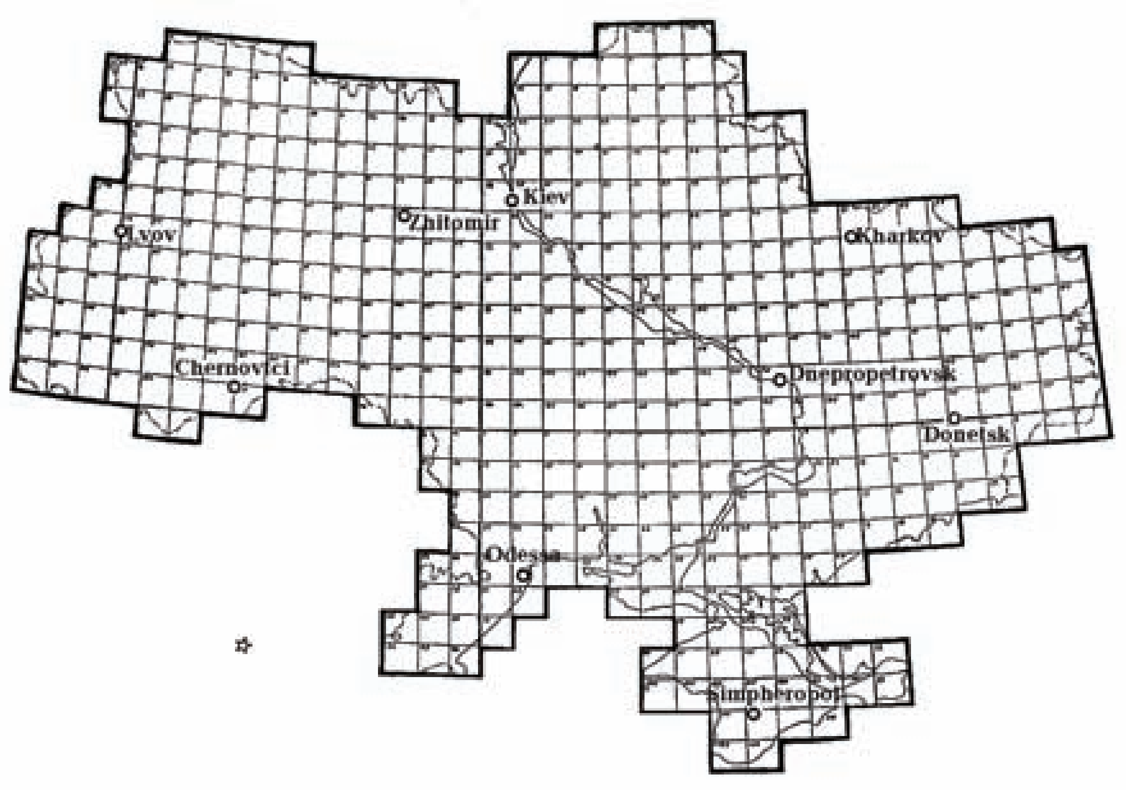

Fig. 1. Raster image of Ukraine.

As targets the mean values of the macroseismic estimations for a given pixel were considered. For Vrancea earthquakes five training sets were formed: in three of them as targets macroseismic evaluations of ’77,’86, and ’90 earthquakes were used. In fourth, for the pessimistic scenario, the worst of the first three were selected. In fifth the first three and 26 pixels of known macroseismic evaluations of ’40 Vrancea earthquake were integrated. As an example on Fig. 2 the izoseismal map for Ukraine of Vrancea ’86 earthquake and pessimistic scenario for XX century quakes are presented.

When compiling the training set for the neural networks for simulation of shaking intensity caused by the single event, such parameters as hypocentral depth and magnitude are not valid as parameters, because they are identical for all vectors-objects of training set and therefore not informative. Using the macroseismic estimations of four earthquakes a neural model allows to integrate these parameters and, due to a capacity for generalization, to model the shaking intensity, caused by a source with characteristics, different from such, used for training, what is shown on Fig. 3 for the extreme parameters of Vrancea source known from historical retrospections.

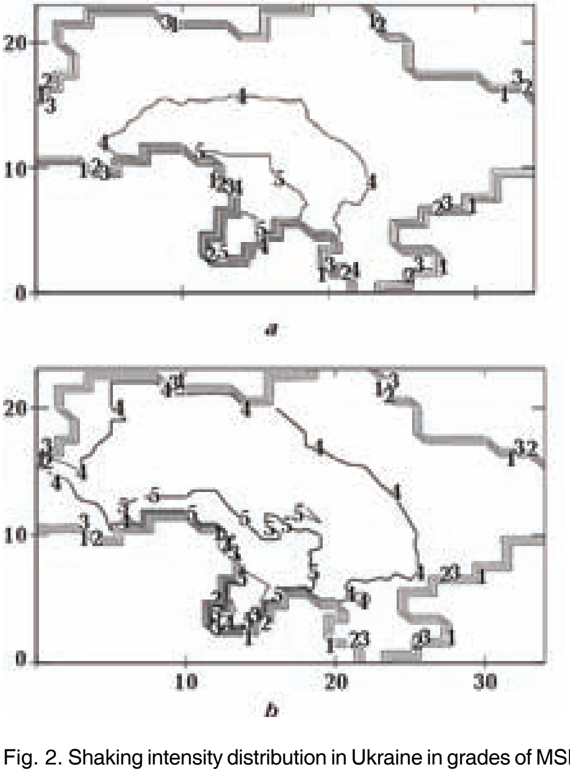

Fig. 2. Shaking intensity distribution in Ukraine in grades of MSK-64 scale for Vrancea1986 earthquake (*a*) and pessimistic scenario for strong Vrancea XX century earthquakes (*b*).

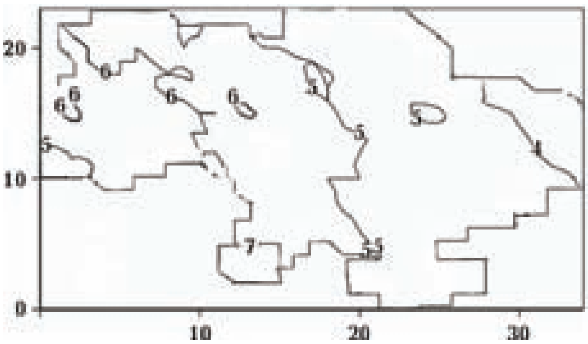

Fig. 3. Prediction of shaking intensity distribution in Ukraine in grades of MSK-64 scale for Vrancea, M=8.1, *h*=150 km.

Microzonation of Yalta. Big scale seismic zonation, obligatory for construction of civil and industrial objects in seismoactive regions, must be realized with due regard for number of factors concerning not only physical and mechanical properties of soil, their geological and morphological characteristics but also using some standard assessments relating these characteristics with responses to possible seismic force. The neural network can solve this problem.

Table 2. Components of vector parameters for Yalta neural model

Parameters	Units	Range
Magnitude	Richter	3.7—6.8
Source depth	km	17—22
Range	km	120—170
Back azimuth	Degree	18.2—26.8
Soil type	Boolean	0.1
Sediment thickness	m	2—20
Water table	m	0—20
N-W extent	Fault #	
N-E extent	Fault #	
Elevation	m	25—300
Tilt	Degree	15—30
Exposition	Degree	90—315
Shaking intensity	MSK-64 scale	3.6—8.3

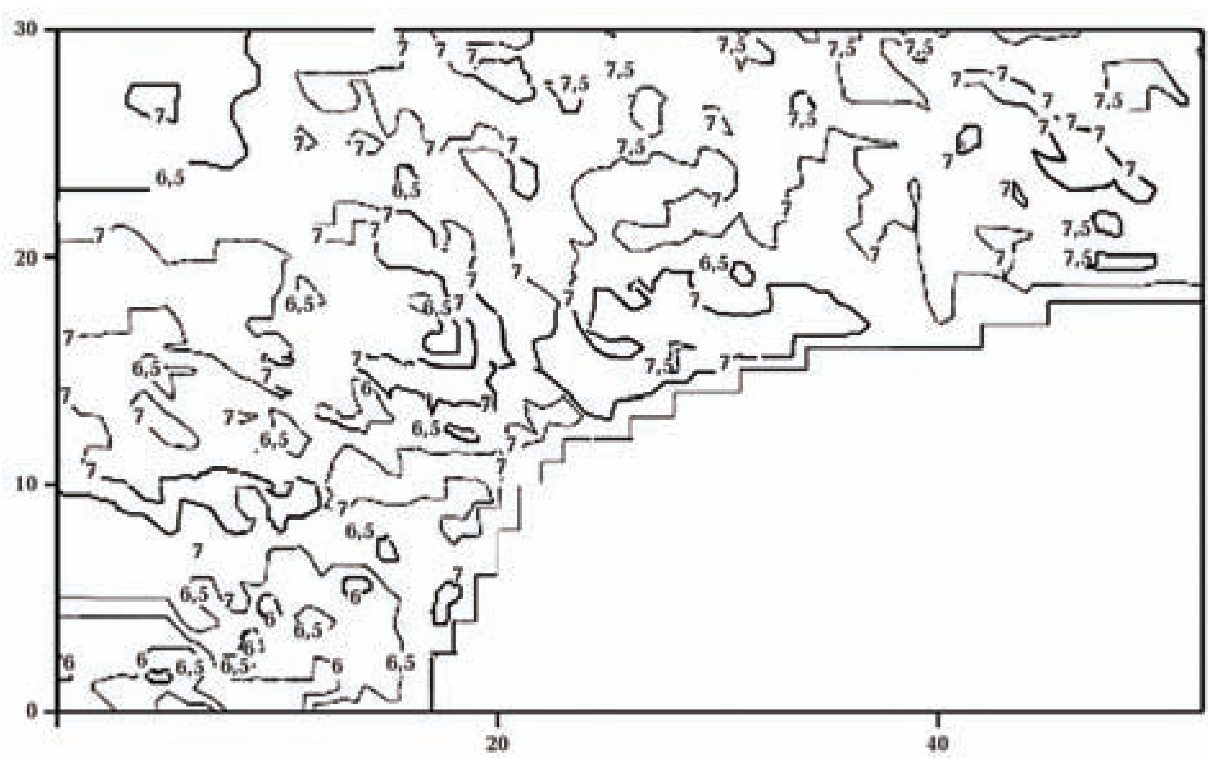

Fig. 4. Prediction of shaking intensity distribution in Great Yalta in grades of MSK-64 scale for ’27 Yalta earthquake type.

Based on macroseismic evaluations of Yalta ’27 and ’80 earthquakes, according to the algorithm used for Vrancea case, for parameters describing the geological medium and listed in Tab. 2, the neural network was trained and used for imitation of the shaking intensity behavior on Great Yalta terrain (Fig. 4).