Advanced Thematic Mapping: GIS/Neural Networks Application for tracking isoseismic lines

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Abstract: - Possibility of making queries on a spatial database, in order to obtain a decisional support is one of the most interesting features of GIS systems. This is possible through the expression of information which are implicit into database and useful for Geoprocessing operations in order to make a sort of data clustering. However, it is not sufficient to represent a priori non-modeling interactions, even if they are present into the informative layers. Case study presented in this paper just concerns this category, taking into account tracking of isoseismic lines on a well-known geographical area. It is very useful in order to generate an affordable map for seismic risk. Proposed procedure, exploiting Neural Networks, can retrieve information about isoseismic lines propagation, starting from information related to examined territory, hypocenter of considered earthquakes, and seismic intensity calculated by standard procedures. Preliminary results we obtained have been used in a GIS software in order to create an Artificial Intelligence informative layer (called OverlayAI). Experimentation carried out shows a preliminary nature and needs further tests and refinement; however, it illustrates useful results to realize an operative plan based on perception of seismic risk in a defined territory.

Key-Words: GIS - OverlayAI - Thematic map - Neural Network - isoseismic lines - earthquakes - seismic hazard.

1 Introduction

Periodically in Italy earthquakes occur with important consequences on social and economic plan; this situation led the institution and the corporate body to define indexes and zonings profits to observe more seriously the subject areas of the country to such type of calamity. An example among all is seismic normative, that predisposes the anti-seismic requisite suitable for the new constructions in specific zones of the Country. Generally such norms are tied up to the concept of seismic risk, high-level interpretative. It is a combination of several factors of vulnerability and value (type and age of buildings and infrastructure, population density, land use, season and time of day when the earthquake occurs), but mainly of seismic hazard area analyzed. This last factor is defined, in first approximation, as the likely level of "shaking" of the soil associated with the occurrence of an earthquake, whose epicentre is the area of analysis which refers to the study of risk which in neighbouring point..

The aim of this work is to provide a contribution for the generation of maps of seismic risk. They have both prevention and decision support in case of immediate response to a seismic event, since, for example, useful for planning interventions to rescue the people or to speak in defence of the existing building stock (particularly of cultural interest). The case concerns the province of Reggio Calabria, as well as some adjacent areas. Of course, the preliminary nature of research means that it is not exhaustive of the topic dealt with by presenting a methodology but with a view (supported by preliminary results obtained by appropriate simulation software).

Today the evaluation of seismic hazard is characterized by: analyzing and cataloguing of earthquakes occurring and related databases; characterization of the seismic source in terms of spatial-temporal distribution of earthquakes, mapping of active faults, geodetic estimates of crustal deformation; geodynamic models; a model for the "ways of mitigating the macro seismic intensity".

In particular, the attenuation model is the basis of the hazard using data and information derived from other elements on listed. The typical result underlying this stage is by lines (isoseismic), plotted on different types of topographical data, which encompass areas such as the earthquake intensity was homogeneous.

In literature the most widely used models for tracking isoseismic lines are based on formulation

CRAM (Berardi et al., 1994) and Grandori (Grandori et al., 1987). These methods calculate the variation of the intensity of energy use from epicentre associated parameters which are constants obtained by statistical calculations operating on the observations of past events in the area concerned, and are designed to model the many variables that influence this type of forecasting, such as surface characteristics of the territory. These types of models are integrated and there are finite element models, which have the disadvantage of requiring many computational resources compared with a precision not entirely necessary, but inadequate if it requires the calculation of risk is updated in real time and seismic event occurred.

The definition of an hazard map is obtained in this work using a combination of artificial intelligence in an integrated GIS (OverlayAI) for determining the attenuation of macro seismic intensity, and various tools of the same GIS software.

2. An alternative way to speak about GIS

In our meaning, a layer L is a subset of the cartesian product S × G, in which S = S1 × S2 × … × Sn is a set of alphanumeric data organized within n different fields to form (as it's usually said) a record and G is a set of geometric entities, each belonging to the same plane π, such that, if (s1, g1), (s2, g2) ∈ L and g1 = g2, then s1 = s2 too. Of fact, if (s, g) is an arbitrary element of the layer, that's to say a feature, then s is an n-dimensional array whose i-th component consists of a sequence of symbols all belonging to the same alphabet, both proper of human langua-ges or typical of machine ones. In this sense, the set of all the records which appartain to the same layer can be usefully represented by a table consisting of n columns and m lines, where m is the layer cardinality, i.e. the number of its elements, always supposed to be finite, for practical requirements.

Then you assume that, for every i = 1, 2, …, n, Si is a structured set, in which you have eventually defined not only one or more internal operations like addition or multiplication, as in the typical case of numeric data, but also relational operators of a manifold kind (for example, operators of comparison).

With reference to the set of the geometric data, within this artiche we assume G may be specialized, in practice, into three fundamental typologies:

- the set Λ of all points;
- the set Σ of all open polygonals, or polylines;
- the set Γ of all not woven polygons.

In this sense, the GIS database is just the union set among k layers L1, L2, …, Lk. Querying operations executed inside a GIS consist essentially of searches performed on the elements of one or more layers, and they are effected by a suitable composition of a whole range of primitive operators, already available among the base functions implemented in the maximum part of general purpose GIS softwares (for example, ArchiGIS, GRASS, MapInfo), declared to operate both over the geometric data in the layer - as in the case of a spatial intersection or when you may be interested in a buffering operation by proximity - or over the respective alphanumeric ones, in which case the search usually employes the typical structures of declarative languages (for example, SQL is a frequently used solution).

2.1 Towards the A.I. operators

From an abstract point view, an n-ary operator on layers is a function Φ(·): L1 × L2 × … × Ln → L, where L1, L2, …, Ln and L are layers related to the same GIS system. To state an example, standard intersection may be applied on two layers L1 ⊆ S1 × Γ and L2 ⊆ S2 × Γ as an operator int(·): L1 × L2 → L, in which, if (s, g) ∈ Im int(·) ⊆ L, then s = (s1 : s2) and g = g1 ∪ g2, where (s1, g1) ∈ L1 and (s2, g2) ∈ L2 (see figure 1).

Here and so in the following, we assume (s1 : s2) denotes the operation of merging between the m-tuple s1 and the n-tuple s2, if S1 = S11 × S12 × … × S1m and S2 = S21 × S22 × … × S2m.

This not standing, within the targets proper of this article, we're going to consider a special class of generalized operators in the form Φ(·): L × F1L → F2L, where L = {(s1, g1), …, (sn, gn)} is supposed to represent a layer of points, polylines or polygons; F1L = {L11, L12, …, L1r} and F2L = {L21, L22, …, L2s}, on the other hand, are two families of layers, each being characterized by a specific geometric typology.

In practice, the key concept is that our generalized operators act mapping every couple of operands not into single elements of a layer, but into a whole layer, in a way which is quite different from the correspondence classically ensured. Specifically, we're fixing firstly our attention on the A.I. intersection operator.

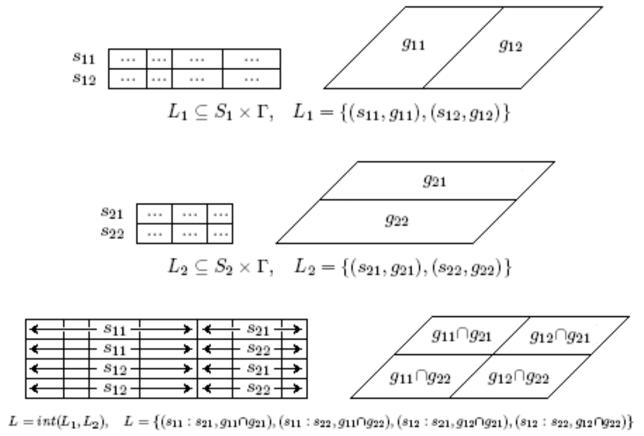

Fig. 1 - A representation illustrating the behaviour of standard intersection regarded as an operator.

2.2 Algorithm used and implementation in GIS

The generation of a thematic map of seismic hazard along the lines suggested by the authors, place in several stages, using different data structures organized as a GIS layer. There is, thus:

- a layer of epicentres point where the features are the outstanding epicentres of suitable seismic events collected by the historical database of the National Institute of Geophysics and Vulcanology (INGV);
- a layer classifying the geology of the area examined;
- and finally a TIN layer for representing elevation of the land.

The first step is the selection by the user of one or more epicentres and the consequent generation of a layer with polygonal features where the borders of the polygons are isohypse describing the attenuation of macro seismic intensity.

The operator which creates this layer has been built within the GIS system with a neural network (Barrile, Cacciola, 2006), which implements the function implication of propagation of the earthquake. To implement the model it has been assumed that this function has the following dependencies:

$$P_j(l) = f[\,p_A, M_j(l), H_j(l), \theta_j, P_j(l-\Delta S), \Delta\omega\,] \qquad (1)$$

Where θ_j where is the angle indicating the direction along which the place of j-th simulation; p_A was the epicentre of the earthquake,; l the distance from a generic point epicentre; $M_j(l)$ and $H_j(l)$ are respectively the coding (done by a natural sequence) of the layer surface geology and altitude above sea level to a point at distance l from epicentre and towards j-th direction; $P_j(l)$, is the power associated also, to the point of polar coordinates l, θ_j.. While $P_j(l-\Delta S)$ is the power associated with the point lying along the j-th, but at the distance $l–\Delta S$. ΔS, , finally, is a constant used to determine, with solving algorithm, the items for which will be calculated, by the way, the power of the seismic wave front..

Specifically the activities of algorithm (iterative), responsible for tracking isosisme take place in the way described below. Starting from the supposed power already calculated on a point of coordinates $l_{i,j}$, θ_j. – where $l_{i,j}$ is the distance from epicentre of a point lying along the j-th direction and, simultaneously, on the i-th isosisma - and expressed as $P_j(l_{i,j})$, or $P_2(l_{1,2})$ (nel caso di figura 1), (in case of Fig. 1), is calculated at the point of coordinates $l_{i,j}+\Delta S$, θ_j (illustrated $l_{1,2}+\Delta S$, θ_2), the power $P_j(l_{i,j}+\Delta S)$. That is, at this point, compared with the value of power $P_{j-1}(l_{i+1,j-1})$ (illustrated $P_1(l_{2,1})$). If this value is greater iteratively proceed along the j-th direction (in Figure j = 2), until we reach a point, whose power values are comparable as shown in (2).

Finally, the power values calculated in iterative manner are obtained by a neural network that implements the function (1).

$$\frac{P_j(l_{i,j}+\Delta S)}{P_{j-1}(l_{i+1,j-1})} \cong 0.02 \qquad (2)$$

The result is similar to what is shown in Figure 2

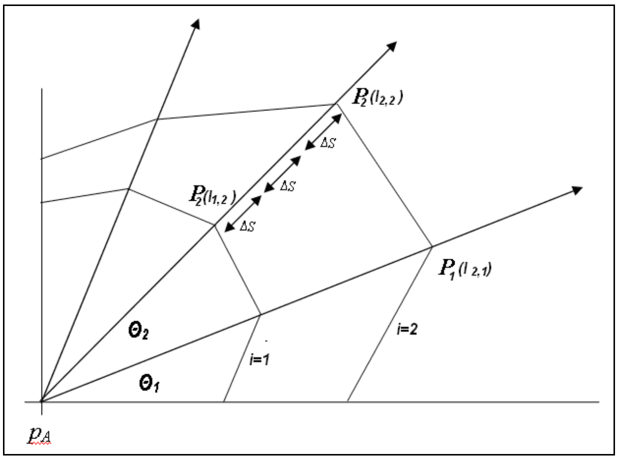

Fig. 2 - Tracing the isoseismic lines by the OverlayAI

For completeness, we note in (1) a dependence on a certain interval of frequency for is not clearly linear a dependence of issue with this last parameter.. This figure was not included in the simulations because experiments using neural network showed that its ability estimative generalizing is approximately independent of the quantity in question. This practice was also considered acceptable for the preliminary nature of the trials, which must not lose their significance in terms of scientific value.

In our meaning, the A.I. intersection is definied in terms of an operator $int_{\mathrm{A.I.}}(\cdot)$: $L_{\mathrm{P}} \times F_{1L} \rightarrow F_{2L}$, where $L_{\mathrm{P}} \subseteq S_{\mathrm{P}} \times \Lambda$ is a layer of points, intended as *sources* of a certain typology of propa-gating signal; F_{1L} and F_{2L} are classes of polygonals layers, in which $L_1 \subseteq S_1 \times \Gamma$ and $L_2 \subseteq S_2 \times \Gamma$, if $L_1 \in F_{1L}$ and $L_2 \in F_{2L}$, given that Λ and Γ are referred to a same geometric plane π.

Without any necessity of being too specific, we assume that S_1 contains at least the fields necessary for any processing involved in the definition of the A.I. intersection.

To make this aspect clear, we say the single polygon within the image-layer of our operator is built employing a neural network which, scanning the time at successive instants $t_1, t_2, \ldots, t_{\mathrm{m}}$, for a certain $m \in \mathrm{N}$ (all computed starting from $t_0 = 0$ sec), estimates distances $r_{\mathrm{j}}^{1}, r_{\mathrm{j}}^{2}, \ldots, r_{\mathrm{j}}^{\mathrm{n}}$, expressed in a suitable metric unity u, reached by the advanced front of an impulsive signal of assigned magnitude, generated at the source-point P and proceeding along the half-line traced from P in the direction pointed by the angle $\theta_{\mathrm{j}} = 2\mathrm{j}\pi/N$ (where $\mathrm{j} = 0, 1, \ldots, N-1$), which results from the anticlockwise splitting of a full angle into N equal parts, with respect to a polar reference system centered in P. Of fact, the generic $r_{\mathrm{j}}^{\mathrm{i}}$ is calculated according to the characteristic recursive relation:

$$r_{\mathrm{j}}^{\mathrm{i}+1} = r_{\mathrm{j}}^{\mathrm{i}} + \mathrm{f}(n, t_{\mathrm{n}+1}, t_{\mathrm{n}}, \ldots, t_1, r_{\mathrm{j}}^{\mathrm{i}}, P, L), \quad (3)$$

where $r_{\mathrm{j}}^{0} = 0\,u$; $\mathrm{f}(\cdot)$ is a multivariable function valued in P^{+} and definied on a certain discrete subset Ω of an euclidean space of type P^{p}, for a suitable $p \in \mathrm{N}$; $P \in L_{\mathrm{P}}$ and $L \in F_{1L}$ identify the operands mapped by $int_{\mathrm{A.I.}}(\cdot)$, which are here intended as argument of $\mathrm{f}(\cdot)$ to represent generically all the alphanumeric and geometric data effectively involved in the elaboration ac-complished by the neural network. For example, with respect to the applications to the study of a propagating seismic signal of which you know the source position and the amplitude of the mechanical impulse emitted at the instant $t_0 = 0$ sec, we shall consider the relation $r_{\mathrm{j}}^{\mathrm{i}+1} = r_{\mathrm{j}}^{\mathrm{i}} + (t_{\mathrm{n}} - t_{\mathrm{n}-1}) \cdot v_{\mathrm{j}}^{\mathrm{i}+1}$, where $v_{\mathrm{j}}^{\mathrm{i}+1}$ represents the speed which is proper of the signal while it's running from the point $r_{\mathrm{j}}^{\mathrm{i}}$ to the adjacent point $r_{\mathrm{j}}^{\mathrm{i}+1}$ along the direction addressed by the angle θ_{j}, for every $i = 0, 1, \ldots, n$. and $j = 0, 1, \ldots, N-1$. This speed is calculated employing the alphanumeric and geometric data included within the polygonal layer passed as an argument for the A.I. intersection operator and specifically containing sampled punctual informations about the PSD (power spectral density) of the geological bed.

Once completed the phase of learning, the neural network which the system of processing interfaces itself to is capable to extrapolate the PSD of every point in the geological bed starting from the sampled values stored inside the GIS, repeating this procedure for every layer $L \in F_{1L}$. So you are guaranteed to obtain a suitable approximation of the signal propagating speed at *any* point of the geological bed, even if this doesn't belong to the our sampling set. Hence it's necessary to admit, as principle, every $L \in F_1(L)$ has one or more fields describing by samples (ideally with continuity) a class of parameters on which the propagation of the seismic signal is dependent. So, if $((s, g), L)$ represents the generic operand passed as an argument to $int_{\mathrm{A.I.}}(\cdot)$ and we put Im $int_{\mathrm{A.I.}}(\cdot) = \{L_{01}, L_{02}, \ldots, L_{0\mathrm{r}}\} \subseteq F_{2L}$, under the hypothesis that r is the number of sources included within the punctual layer L_{P}, we find the generical feature $(s_{\mathrm{i}k}, g_{\mathrm{i}k}) \in L_{0k}$, for any $k = 1, 2, \ldots, r$, is such that: $g_{\mathrm{i}k}$ is the polygon having as internal and external frontiers, respectively, the two closed polygonals obtained linking by a segment all the adjacent points $r_0^{\mathrm{i}}, r_1^{\mathrm{i}}, \ldots, r_{N-1}^{\mathrm{i}}$ and $r_0^{\mathrm{i}+1}, r_1^{\mathrm{i}+1}, \ldots, r_{N-1}^{\mathrm{i}+1}$ traced starting from the source point P_k and stored within the processing system including our neural network into a sort of matrix structure, as illustred in figure 2; and $s_{\mathrm{i}k}$ is a 3-tuple $(s_{\mathrm{i}k}^{1}, s_{\mathrm{i}k}^{2}, s_{\mathrm{i}k}^{3})$ where $s_{\mathrm{i}k}^{1}$ and $s_{\mathrm{i}k}^{2}$ save, respectively, the signal amplitude on the internal and external frontier of $g_{\mathrm{i}k}$, and $s_{\mathrm{i}k}^{3}$ reports the absolute coordinates of the source point P_k.

3 Case of study: geological - structural features of examined area

The seismicity of the territory of Calabria is a constant in its history.

The seismic zonation of the territory of Calabria, to predict and mitigate the effects in a seismic area in historical times more frequently and violently than others subject of earthquakes, represents an important research topic on which can compare scientists, geologists, geotechnical and structural engineers.

For trials conducted in this publication we have used the data on the earthquakes of 1783 of Tropea and Messina in 1908, and the area chosen for the study is placed into the southern part of Calabria, in the province of Reggio Calabria and in neighboring areas; as the most representative on a regional scale to the subject matter.

That territory, as we shall see in this paragraph, shows more significant both in number and size of settlements as well as for geomorphological characters (from the Tyrrhenian coast to the watershed Tirreno - Jonio) and, essential reason, for number and intensity of destructive earthquakes relatively more recent (the more recent and better documented, in fact: 1783, 1905, 1908).

The area examined lies therefore in the broader regional context of the northern massif of Aspromonte that geographically occupies the southern tip of Calabria.

It represents the central-southern of Calabro-Peloritano Arc, bounded on the north by the Sangineto line (fault trascorrente left) and south from the Taormina (fault trascorrente right), which consists of crystalline and metamorphic terrain. (Fig. 3).

The Calabro-Peloritano Arc consists of two areas divided by an undefined alignment Capo Vaticano - Del Valle Mesima - Soverato.

The area examined in this article falls within the southern sector of Calabro-Peloritano Arc. (Fig. 4).

The Aspromonte Massif, given its complexity, has been the subject of several geological interpretations. This massif as a whole is made up predominantly of metamorphic medium-high, with masses of granitic intrusions that, with a core corresponding to the area of Montalto, appear to west to the Tyrrhenian coast between Villa San Giovanni and Laureana.

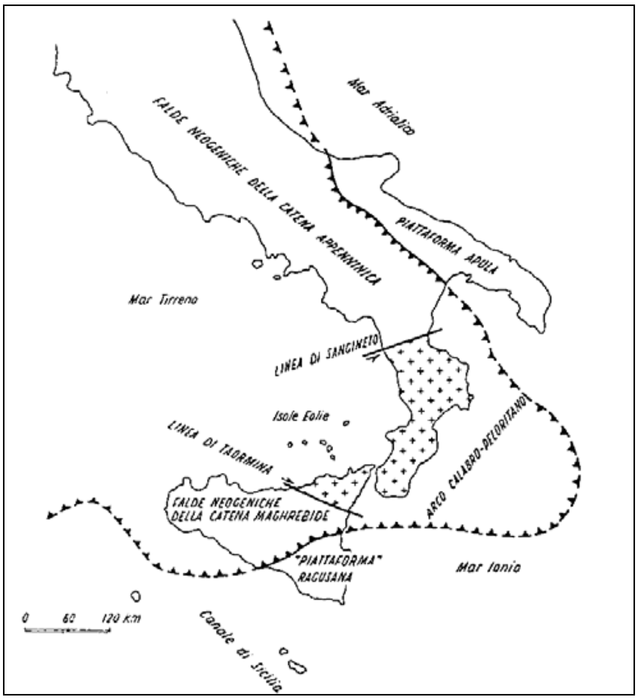

Fig 3 - Scheme of the Apennine-Maghreb in the debate (by Amodio-Morelli et al., 1976)

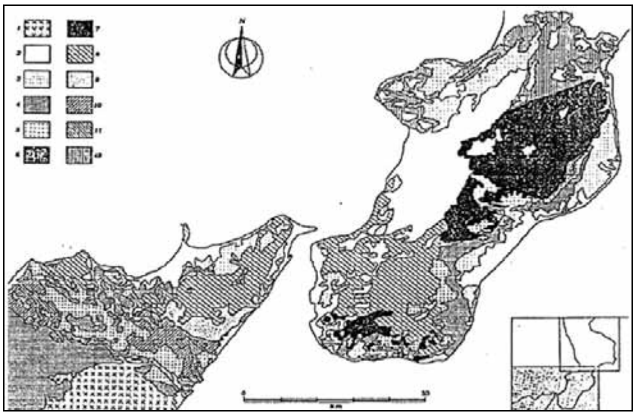

Fig. 4 - Schematic geological structure of southern calabro-peloritano arc (from Tortrici, 1982). 1= Etnean vulcanite; 2= medium sequences suprapliocenic-Pleistocene; 3= Tortonian sequences infrapliocenic; 4= unity Sicilian; 5= formation of Stilo-Capo d'Orlando; 6= unit of Stilo, coverings Mesozoic; 7= unit Stilo , basement; 8= Aspromonte units, 9=units Mandanaci; 10= units Longi-Taormina, coverings Meso-Cenozoic; 11= Longi Taormina units, basement; 12= crystal units of Northern calabro-peloritano Arc

The tectonic of Aspromonte appears extremely complex. There are indeed conflicting interpretations offered by different schools of thought about the geometry and evolution of the area.

In the area studied in detail the main structural elements on the Tyrrhenian side are represented by horst rock crystal backbone of Serre in the direction NE-SW cut transversely (crossout) and divided by horst of Aspromonte and graben of Siderno with NW-SE trend (except paper) where the fault goes right trascorrente Monte Poro - Siderno; by horst of Sinopoli - Delianuova - Cosoleto and less than that of Palmi. AN and NW of horst said there is a vast Graben in Piana di Gioia, filled by sediments of Quaternary and divided by horst north of Capo Vaticano and less than that of Nicotera by a normal fault with NW-SE direction.

In the area examined in this study were therefore identified some faults seismogenetic mechanism with normal and partly trascorrente, one still very evident today, at St. Cristina D'Apromonte, Oppido M., Cittanova and, more than 25 km, followed by gradual wake up to a hundred km

Moreover, the faults are generally normal mechanisms in the internal part of the chain, while in the more external inverse. The main fault system is still active (Fig. 5).

Fig. 5 - Neo-tectonic area of southern Calabria derived from satellite image (from Guerricchio A. et al., 2004). The seism-tectonic zones are designated as in literature. The plain of Gioia Tauro, real pit tectonics, rejuvenated by the earthquake of 1783, is shown in gray. The reactivated fault is shown with two arrows and show the character of trascorrente right.

One of the strongest earthquakes that shook the region of Calabria (the Messina earthquake of 28 December 1908, M. 7) produced an average displacement of about 1.5 m at fault.

The shocks associated with earthquakes in February and March 1783 were located along the tectonic ditch (graben) of Mesima, with trend isoseismic lines, elongated NW-SE and EW, following the major structures with longitudinal and transverse migration of fireworks to north (Fig. 6).

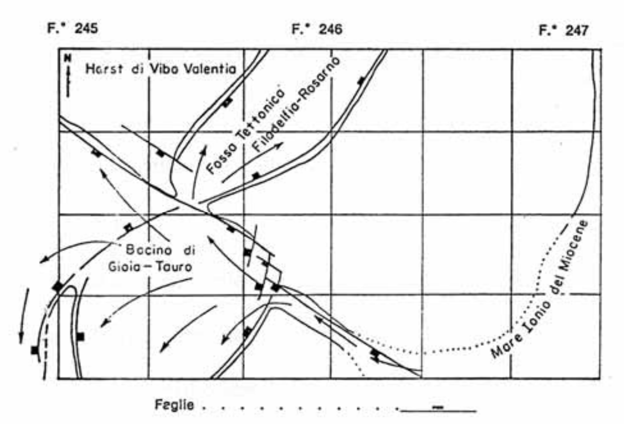

Fig 6 - Diagram of the main tectonic structures.

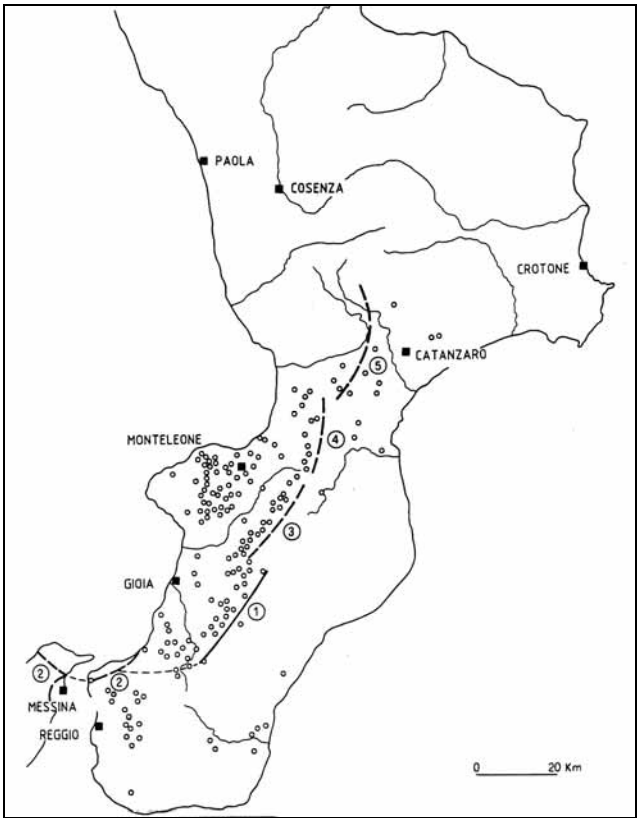

Fig. 7 - Scheme migration epicentral area during the seismic period between February 5 of 1783 and March 28 of that year, with details of cities and countries destroyed (by V. Cotecchia et al., 1986). The migration of the epicentral area was in the following order: 1) February 5, 2) February 6, 3) February 7 (at 20:00) 4) February 7 (at 22:00) 5) March 1; 6) March 28. Particularly in the rupture in the study was observed on the surface for a length greater than 25 km.

To understand how important can have tracking isoseismic lines in the study of seismic phenomena we can observe the following image (Fig. 8). With reference to the earthquake of 1783 the area was mesoseismic bounded by Barbano et al. (1980): within a line of X isoseismic in scale MKS - 64th.

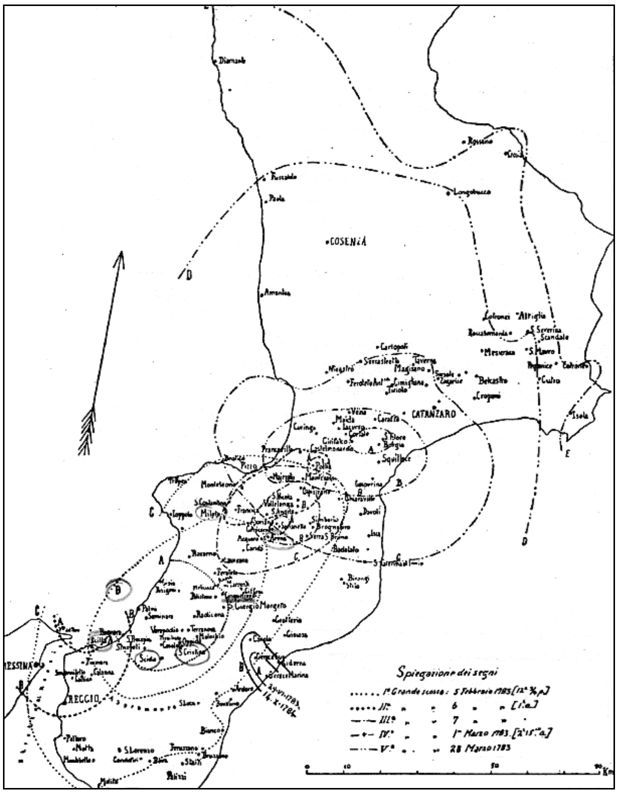

Fig. 8 - Scheme migration epicentral area during the earthquake of between 5 February 1783 and March 28 of that year, with details of cities and countries destroyed (by M. Baratta, 1901).

Its shape is approximate to that of an ellipse whose very elongated larger diameter is provided at approximately NE-SW, is roughly bounded by a line passing under Nicotera, at Miletus, at Arena, following the ridge of Appennino, runs up the slopes of Aspromonte somewhat below S. Cristina and Scido, somewhat below Scilla (Fig. 9).

In mesoseismic area Barbano et al. (1980) distinguished also an epicentral area which falls within the line of isoseismic XI scale MKS - 64th.

The least affected area is bounded by an isoseismic line of IX grade scale MKS - 64; in it the damage was far less and the destruction of buildings was not total.

Fig 9 - Satellite image. Scheme migration epicentral area during the earthquake of between 5 February 1783 and March 28 of that year, with details of cities and countries destroyed (by M. Baratta, 1901).

We can then observe that the major areas of disturbance for clastic fault were thus a key role in the earthquake, as it turned out to be as seism-tectonic lines and thus acted seism-generators by locally enhancing the intensity of the earthquake, or by generating their the same motion earthquakes. Furthermore, to enhance the intensity of earthquakes contributed another geo-structural condition: the coverage of small thickness of sedimentary rocks loose, transgressive on the base stone much more rigid. Indeed, during the earthquake of 1783, the strata consisting of clay and less skidding on the crystalline basement, causing the usual phenomena of cracks, crevices, overlaps and obstructions, always dragging behind whole towns.

It thus witnessed the destruction of everything that was based on loose sedimentary rocks, while the centres located in the mountain or rock crystal, which are very close to epicentre, not suffered damage as showy.

This shows that the thickness of sedimentary soils hasn't any function in damping of seismic intensity, and indeed contributed to his exaltation.

The new seismic classification is based on a study of probability, which takes into account all the seismic events occurred in Italy since 1000. Then using the statistical criteria, it was possible to prepare for "seismic hazard maps", which tell us what are the areas in Italy where it is most likely to arise as an earthquake of a certain importance.

4 Experimenting GIS

The neural network model described in a previous section was used to obtain an estimate of the hazard map in the province of Reggio Calabria and the surrounding areas. In this case, the area of greatest interest has been identified with the area extending from Tyrrhenian Tropea (VV) to Reggio Calabria and the Aspromonte massif immediately behind it.
For the experiments carried out we used the data on the earthquakes of 1783 of Tropea and Messina in 1908. In this case, the power seen at the end of isoseismic lines tracking is seismic intensity on the magnitude of individual earthquakes, as it has been rebuilt step by step from the INGV staff from bibliographical data and historical archives (Figg. 10 - 11 - 12).

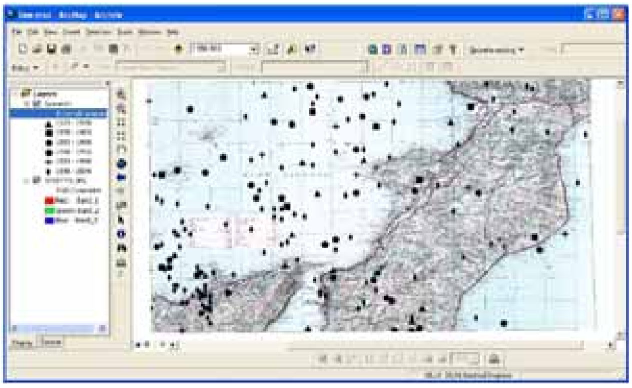

Fig. 10 - Evolution of seismicity through time. The image emphasizes the characteristics of "seismic migration". and at the same time, we can highlight areas with a greater frequency of occurrence than others..

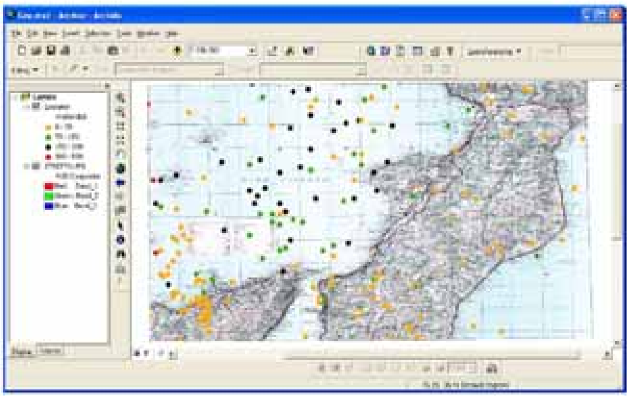

Fig. 11 - Evolution of seismicity with depth. The layer above confirms what was said previously about the situation on the Geodynamics of the Strait area. As you can see, in fact, there is a migration of seismicity focal depth from the South-Southeast to North-NorthWest to have significant seismicity to depths of 300 km and beyond.

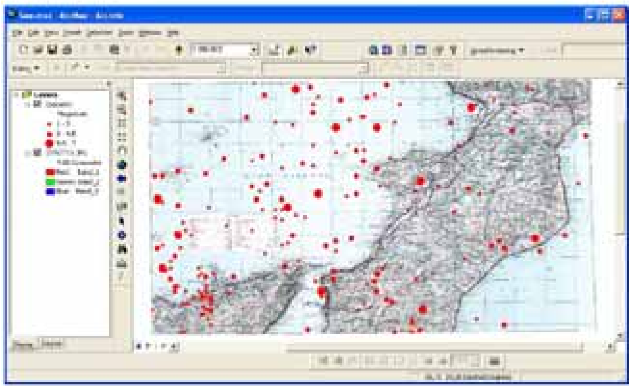

Figure 12 - Representation of seismic events in the study in accordance with the classification scale of magnitude. The layer covering the data on the locations of earthquakes, using the range of magnitude, ranging respectively from 1.0 to 3.0 (identified by small circles), from 3.0 to 4.5 (identified by circles of intermediate size) and from 4.5 up (identified by larger circles), represented in Figure 6, allowss instead to identify those areas that may present a high hazard (Protection Civile), especially in terms of damage that a strong earthquake could cause to property and / or people because of the special hydro-geographical conformation of the examined territory.

In such cases, as evidenced by (1), it was necessary to consider the varied morphology of the calabrian land estimating the height of various points from the level of the sea and the geological hazards of different types of materials present in the area. They are the results of the sediment in different geological epochs, and therefore have a different behaviour to the reflection and / or transmission of seismic waves and the presence of either type of material has been highlighted by an appropriate numerical coding of the material itself both in training and in testing the neural network. This coding was implemented associating to each type of material a positive integer.
An example of the results obtained from experiments performed is shown in Figure 13, where there are two layers generated by the operator OverlayAI and modelling isoseismic lines in the Aspromonte area.

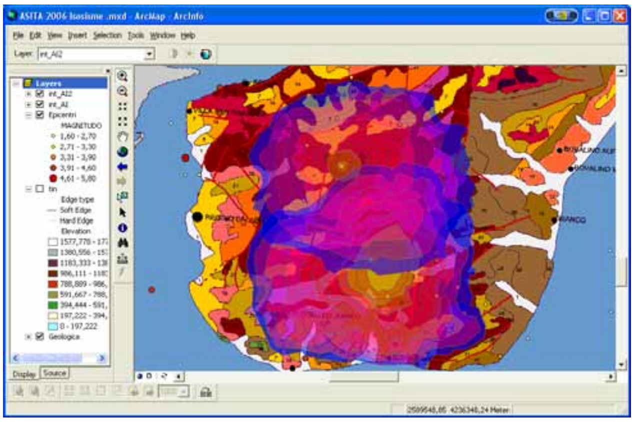

Fig. 13 - Two Layer modellers of isoseismic lines

Figure 14 shows, however, a portion of the TIN layer used to take into account the effect of allowances on the propagation of seismic front. In the figure it refers to a portion of the area falling in the municipality of Reggio Calabria.

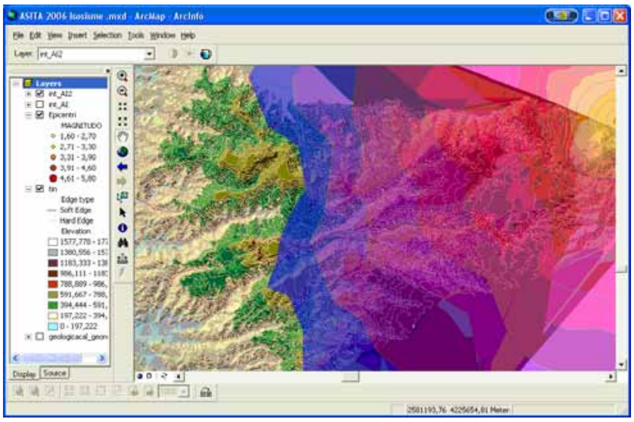

Fig. 14 - The TIN layer used to obtain altitudes.

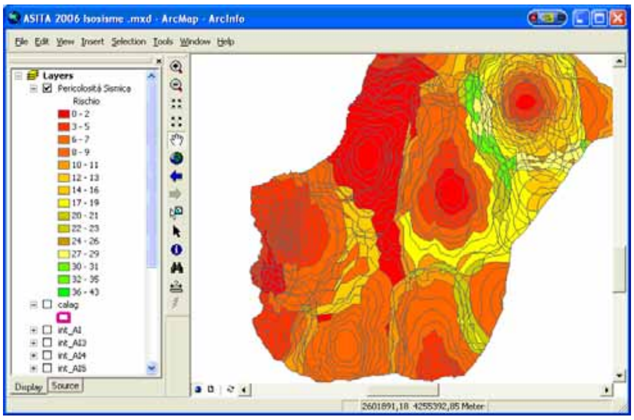

Fig. 15 - Map of seismic risk obtained with the proposed method.

The last step for the calculation of the hazard map is resolved when a transaction standards Geoprocessing Intersect between all layers (generated by OverlayAI), where the polygons are delimited by isoseismic and whose features have the attribute calculated by the neural network in the first phase: here is categorized the intensity of the earthquake on the surface of the polygon itself. This creates a layer where the features are many polygons obtained intersecting the polygons of isoseismic layers, Fig. 15.

The layer resulting from this operation has an attribute where is added an index proportional to the sum of the indices representing the powers of the layers involved in the same operation intersect. The layer therefore represents a ranking of areas according to the mentioned index, the meaning of the zoning thus refers to the probability that a given area being hit by an earthquake of great intensity. For example, a centre, although next to a large number of epicentres "potential", may be less at risk of a centre far away from the epicentres but bounded by a geological stratum (among other factors) that don't dissipates the energy of earthquake.

5 Conclusion

In this work the authors have addressed the issue of building a map of seismic risk. The methods of approach have involved the determination of isoseismic lines for individual earthquakes in a defined geographical area of the Italian peninsula. In this case study the considered area includes the southern part of Calabria.

Through the appropriate use of a Neural Network specially trained and tested on historical data made available by INGV, it was possible to estimate, for every earthquake considered separately, its tracking of isoseismic lines beginning from known data and the intensity the earthquake itself, both the geo-morphological characteristics of the studied area. It was thus possible to implement a GIS layer of artificial intelligence called OverlayAI that, intersecting in a relevant way the isosisme, gives sufficient information about the seismic risk of the area analyzed. That achieved (OverlayAI) is a preliminary result good enough because, if properly overlaid with layers depicting such socio-economic characteristics present therein, can adequately explain the experimental methodology for obtaining a preliminary map of seismic hazard at detailed scale directly integrated in GIS environment, for the purposes of decision support to the various local authorities for the protection and safeguarding public.

We want to stress how different the behaviour of each geographical point to the transmission of seismic waves is due not only to geo-morphological characteristics, but also the type (epicentral, ipocentral, etc.) and the magnitude of the earthquake. Of this dependence was not taken into account in this study given the nature yet only preliminary. The main purpose of this article is to introduce innovations in the structuring of a map of seismic risk from the potential offered by GIS and neural network, with consequent (but not exhaustive) assessment of the proposed method. Future developments of this research will undoubtedly consider this refinement of the model.

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