APPLICATION OF FUZZY METHOD IN QUANTITATING ACTIVE FAUITS ①

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ABSTRACT

This model can extract quantitative index of active faults according to experts' assessmant of some of the active faults, using information diffusion principle and the method of falling shadows of random sets. By it, a lot of ordinary investigators can easily handle expert experience to provide a great amount of information about activefaults and prepare better condition for analysing quantitative influence of active fault upon earthquake damage.

Keywords: information diffusion, random set, falling shadow.

1、INTRODUCTION

Some preliminary conclusions [1-3] have been known about quantitive influenceupon earthquake damage from active fault. They are as follows:

1. The extent of earthquake damage on the earth's surface directlydepends on the seismic magnitude M, and M is relevant to the earthquake fault surface length L, the greatest ground displacement D along thedirection of main fault. The relation can he showed by king-knopoff formula:

$$M = 1.40 + \text{Log}(LD^2) / 1.9 \qquad (1)$$

Where, the unit of L and D is centimetre.

2, In the region such as the western part of the United States andthe northern part of Turkey, the area A of earthquake damage enclosed by various isoseismal lines can be found by the linear formula:

$$\text{Log}(A) = a + bM \qquad (2)$$

where, the unit of A is square kilometre.

3. In the earthquake region with complex tectonic system, that linear assumption is nolonger good. China's Yunnan area belongs to this type.

4. In the zone where the main fault can affect the relation between A and M but the effect is not very remarkable, the relation is gradually divorced from linearity. The North China area belongs to this type.

5. Whether there are active faults, their influence upon the damage area is little in the area where earthquake intensity is Ⅶ or below Ⅶ. And earthquake depth influence

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lesser as compared with active faults,the depth can be neglected.

6.For high intensity area of VII or over VII,the existence of active faults near the epicenter has a great impact on extending the damagearea.

The conclusions of the matter stated above are only preliminary quantitating analyees because there usually are quite distinctive differences between two active faults in type,scale and degree of activity.Therefore these conclusions are roughly made since they are established on the faundation of average quality.They can not satisfy the need of practical engineering [4] , so we have to further study the quantitating processing of active fault.

2.THE MARKING OF ACTIVE FAULT AND EXPERT ASSESMENT

It must be consistent with current common opinion of experts to make a comprehensive description of an active fault in the physical quantity of type,scale and degree of aitivity.That is to say,thequantitating of active faults should follow expert judgement.It needs a transformation process from expert experience drscription to quantitating.

The expert judgement on active fault generally comes from following markings [5] :(1)"Mountain rises from flat land "--the topographical contrast is strong ;(2) There are many deepand narrow canyons;(3) Fault cliff (another name is fault facet) isdistinctive;(4)Often,there is narrow long low-lying land or bog by thefoot of the mountain with fault cliff;(5) Fault clay or the brokenbelt of fault is not cemented;(6) There is springwater coming out alongthe fault.If it is hot spring,the temperature of water and the degree of mineralization are higher;(7) In fault zone plants wither unexpertedly,or special rare plants grows there;(8) The coneof dejecting by the mountain with fault clulf is unusually high or low,and it is not a mathch for the mountain;(9) The Quaternary accumulation by the mountain is quite thick;(10) Debacle or landslide often occurs;(11) There is minor-scale fold and minor fault in the Quaternary accumulation;(12) There are historical epicenters;(13) The local station oftenrecords small earthquake action,and the inhabitants nearby often feel the quakes;(14) There is sign of lurch or leap on the remains of paleofoundation;(15) There are symptoms of disturbance about hydrologicnet or range across active fault zone;(16) The precision measurementsystem set on the fault zone records movement,and the average yearly speed and displacement can be calculated;(17) The geothermal numerical value along the fault is higher;(18) The Quaternary volcanic cone or lava is linear rank;(19)Along active faulf,the numerical value of earth current,earth magnetism or gas generally is higher,and thedifference of distinct site is remarkable.

These markings are correlated.Sometimes there are pseudomorphs.Experts have to carefully abserve to evaluate whether the fault is active and in what degree.To avoid making a mistake,it is necessary toseparate pseudomorphs from the facts.It is not easy to reach the levelof the expert by learning through the usual way of observing faults.However,if the expert experience is quantitative,we will have more laws to fallow in the course of mastering the investigation technique.To some extent we can reach the level of the expert by quantiting method.

Generally speaking,an expert has to be ready to bear a heavy work load if he wants to observe very closely to judge whether a fault is active or not, determine which type the fault belongs to, evaluatescale of the fault and the degree of activity. But the number of experts is very little,and their physical and mental energy is limited. They can not go everywhere to investigate all active faults which may appeararound the country. Meanwhile, there are a large number of middle–agedand young investigators who are full of energy here and there. If theycan master the expert experiences though quantitive method, no doubtmore and more valuable material will be provided, which will deepen our understanding of the impact of active faults on earthquake damage.

Then, what is expert exprience ?

The final comments to several active faults that are typical is expert experience. These comments embody the knowledge of experts.

Quantitating expert experience can be achieved by setting upthe numerical relation between factors and comments. The factors are the markings of active fault. The comments come from experts jugement.

It is impossible to investigate and evaluate hundreds of activefaults very closely by experts in the past few years. Only severaldozen active faults can be studied dy specialists. Therefore, the method of classic mathematical statistics is not the best way for quantitaing in this problem. Obvious noncompleteness compels us totake the method of fuzzy information optimized treating.

3. THE COURSE OF QUANTITATING THE EVALUATION

Let facts set be:

$U = \{U_1, U_2, \ldots, U_{19}\}$ (3)

and comments set be:

$V = \{v_1, v_2, \ldots, v_9\}$ (4)

where $U_i$represents ith marking which was described in last section. Its quantitating depends on the number of samples and the characterof the marking.

Suppose we have a sample set A that came from investigation for n active faults:

$A = \{a_1, a_2, \ldots, a_n\}$ (5)

$a_k$is an element of V in the comment of kth fault. We call A the knowledgesample space. $a_k$was fixed by investigating and analysing charactersrelated to kth fault. When n is about several dozend, $U_i$at most hassix discrete points. for example, we can take:

$U_1 =$ relative height of the contrast about the terrain

$= \{5, 10, 15, 20, 25, 30\}$ (6)

U_{16} = per-year movement speed

$= \{ u_1^{(16)}, u_2^{(16)}, \ldots, u_5^{(16)} \}$ (7)

U_{18} = state of Quaternary volcanic cone and lava

$= \{ 0,1 \}$ (8)

0 means linear rank, 1 means nonlinear rank.

The elements of V in (4) were defined by the following:

v_1:nonactive fault;

v_2:strike-slip,miniature,activity is weaker;

v_3:strike-slip,miniature,activity is stronger;

v_4:strike-slip,large, activity is weaker;

v_5:strike-slip,large, activity is stronger

v_6:wrench fault,miniature,activity is weaker;

v_7:wrench fault,miniature ,activity is stronger;

v_8:wrench fault,large, activity is weaker;

v_9:wrench fault,large, activity is stronger.

The course of quantitating expert experience is to establish afuzzy relation matrix $\underset{\sim}{R}(U \times V)$ from U to V by using A and fault markings which were observed. We also call $\underset{\sim}{R}$ knowledge base that is the numerical expression of expert experiences.

We can use the information diffusion principle [6] and the methodof falling shadows of random sets [7] to get $\underset{\sim}{R}$. The former makes set samples, the latter makes the fuzzy sets that represent concept $v_t(t = 1,2,\ldots,9)$ in the universe U.

The elements $U_1, U_2, \ldots, U_{19}$in U can be divided into two types according to their character.If the marking can be measured by real number,the corresponding element is called diffusible element;if itcan not be measured,the element is called non-diffusible.If U' is a diffusible element,every $a_k$in A can give it a fuzzy set;If U'' is a non-diffusible element,a gives it a set where there only is one point whose function is not zero.For the latter,we say that $a_k$gives U'' a single-point set.

The fuzzy set of a diffusible element can be obtained by using the method of instilling in central point and stratified diffusion [6] .For example,when there are 6 discrete points,coefficent of diffusion is:

$C_6 = (c_1, c_2, \ldots, c_6) = (0.226, 0.193, 0.121, 0.054, 0.016, 0.003)$ (9)

now,if relative height of the contrast about the terrain of k'th fault is 10 metre,we obtain a fuzzy set $\underset{\sim}{U}_1^{(k')}$in U_1:

$\underset{\sim}{U}_1^{(k')} = \{ 0.193, 0.226, 0.193, 0.121, 0.054, 0.016 \}$ (10)

Because a single-point set is a special fuzzy set, we can say that every fault also gives a fuzzy set to each non-diffusible element.Forinstance,suppose,the above-mentiomed k'th fualt is its Quaternary volcanic cone and lava linear ranks,then we obtain a fuzzy set $\underset{\sim}{U}_{18}^{(k')}$in U_{18}: $\underset{\sim}{U}_{18}^{(k')} = \{ 1,0 \}$ (11)

That is to say,from every a_k,we can obtain 19 fuzzy sets in U.The fuzzy setthat came from a_k in U_i is written as:

$$\underset{\sim}{U}_i^{(k)}=(u_{ij}^{(k)}) \qquad (12)$$

where $i=1,2,...,19;j=1,2,...,P_i;k=1,2,...,n.P_i$ is the number of discrete points in U_i.

To establish knowledge basc $\underset{\sim}{R}$ by A given in (5) and their markings,firstly,we must classily elements of A.Suppose,in A,there are D_t elements that their comments all are v_t.This subset of A is written A_t.

Then:

$$A_t=\{a_{k1},a_{K2},...,a_{kDt}\} \qquad (13)$$

Assume $U_i^{(k)}(i=1,2,...,19;k=k1,k2,...,kD_t)$ were abtained from A_t.Write down:

$$Q_i^{(t)}=\{q_{ij}^{(t)}\}=\{\sum_k u_{ij}^{(k)}\} \qquad (14)$$

call $Q_i^{(t)}$ is primary information matrix of v_t.By the theory of falling shadows of random sets,we can know:

$$\underset{\sim}{Q}^{(t)}=\{\underset{\sim}{q}_{ij}^{(t)}\}=\{q_{ij}^{(t)}/D_t\} \qquad (15)$$

is a fuzzy set.

Let:

$$M_t=\max_{\substack{1\leqslant i\leqslant 19\\ 1\leqslant i\leqslant p_i}}\{\underset{\sim}{q}_{ij}^{(t)}\} \qquad (16)$$

Call:

$$\underset{\sim}{R}_i^{(t)}=\{r_{ijt}\}=\{r_{ij}^{(t)}\}=\{\underset{\sim}{q}_{ij}^{(t)}/M_t\} \qquad (17)$$

is a normalizing fuzzy set relevant to v_t in U_i.

Comparatively speaking to $\underset{\sim}{U}_i^{(k)}$ in (12) , $\underset{\sim}{R}_i^{(t)}$ possessed statisticalfeature and it can describe the numeral relation between U_i and v_t.

Let:

$$\underset{\sim}{R}=\{r_{ijt}\},i=1,2,...,19;j=1,2,...,P_i;t=1,2,...,9 \qquad (18)$$

$\underset{\sim}{R}$ just is the conclusion of quantitating expert experiences.

4.APPLICATION OF THE CONCLUSION OF QUANTIATING

In fact,$\underset{\sim}{R}$ is a fuzzy relation matrix from U to V.With appoximate inference formula [8,9] (19) and R,an average investigator may judgefaults more correctly like an expert.

$$\underset{\sim}{V}=\underset{\sim}{U}\circ\underset{\sim}{R} \qquad (19)$$

Operator "o" is max−min type.

For example,let us investigate an active fault,if its relative height of the contrast about the terrain is 15 metre,then,the followingfuzzy set in U_1 is abtained by (9).

$$\underset{\sim}{U}_1=\{0,121,0.193,0.226,0.193,0.121,0.054\} \qquad (20)$$

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And suppose its Quaternary volcanic cone and lava is non−linear rank,

then:

$$\underset{\sim}{U}_{18}=\{0,1\} \qquad (21)$$

....

Let $\underset{\sim}{U} = \{\underset{\sim}{U}_1, \underset{\sim}{U}_2, \ldots, \underset{\sim}{U}_{19}\}$ (22)

Allow U into formula (19) ,we can obtain:

$$\underset{\sim}{V} = \{\mu(v_1), \mu(v_2), \ldots, \mu(v_{.9})\} \quad (23)$$

Suppose:

$$\mu(v_t) = \max_{1<k<9} \{\mu(v_k)\} \quad (24)$$

We know that this fault is $v_t$type by the fundamental rule of maximumfunction.(Note:non-active fault $v_1$is special active fault).

5.CONCLUSION AND DISCUSSION

The model provided in this paper is specially suited for analysingcomplex systems with many factors.In fact,it is a falling shadow from expert comments.It is a pity that the author has not found enough material to establish practical knowledge base $\underset{\sim}{R}$.Therefore,no final conclusion has been reached as to which diffusion means and operator is the best.The model only is a simple method of quantitating.

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