行政院國家科學委員會專題研究計畫 成果報告

台灣地區強地動研究整合計畫--譜震度與活斷層區應變分佈之研究

研究成果報告(精簡版)

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計畫主持人：葉永田

計畫參與人員：碩士級-專任助理人員：蔡坤憲

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中 華 民 國 97 年 08 月 27 日

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

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譜震度與活斷層區應變分佈之研究

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計畫參與人員：高清雲、鍾仁光

成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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執行單位：嘉南藥理科技大學

中　華　民　國　97　年　08　月　27　日

Comparative Study of PGA Attenuation Relations Deduced from Least Squares Method and Genetic Algorithm

Abstract

In engineering applications, attenuation relationship is one of the key elements in a seismic hazard analysis. However, it is difficult to find the optimal solution of coefficients in attenuation model using traditional mathematical methods because of its nonlinearity. Besides, it is not reasonable to use unweighted regression analysis in which each recording carried an equal weight due to nonuniform distribution of data with respect to distance. In this study, least squares method (LSM) and genetic algorithm (GA) are employed as nonlinear regression methods to find the optimal solution of parameters in attenuation model to compare the robustness and predicted accuracy of the two methods. Different weights (equal and unequal weights) of each recording were used to compare the adaptability of the weights for practical application. Considering the hazard and energy radiation of an earthquake, the unequal weight of each recording are defined as function of distance. Moreover, the regression analysis of horizontal peak ground acceleration (PGA) attenuation model in southwest Taiwan was studied.

Key Words: **Attenuation Law, Regression analysis, Peak Ground Acceleration, Genetic Algorithm.**

Introduction

There are several attenuation models that relate a given ground-motion parameter (e.g., peak ground acceleration, PGA) to several seismological parameters of an earthquake, such as earthquake magnitude, source-to-site distance, style of faulting, and local site conditions [1-3]. The attenuation model is computed by regression analysis. Regression analysis is a statistical technique for investigating the relationship between one or more variables based on a set of observed data. The variable of interest is denoted as a response (dependent) variable, while all other variables are called predictor (independent) variables. In general, the relationship between a dependent variable and independent variables is unknown, and a regression model is proposed as an idealized and simplified version of the relationship. Since observed data usually exhibit some degrees of variability, a statistical analysis is performed to determine the regression coefficients based on the observed data. The regression methods used in this study include least squares method (LSM) and genetic algorithm (GA).

Empirical equations for predicting strong ground motion are typically fit to the strong-motion data set by least squares method (LSM). Campbell (1981) used weighted least squares in an attempt to compensate for the non-uniform distribution of data with respect to distance. However, traditional regression analysis methods (e.g. least squares method) have some drawback, such as searching the local optimal solution and the gradient of objective function needs to exist.

Genetic Algorithm (GA) is a robust search technique based on the principles of evolution [4-5]. Extensive research has been performed exploiting the robust properties of Genetic Algorithms and demonstrating their capabilities across a broad range of problems. These evolutionary methods have gained recognition as general problem solving techniques in many applications, including image processing, training of neural networks et al. Unlike traditional regression analysis methods, GA searches the global optimal solution and does not need to calculate the gradient of objective function and thereby makes it a highly promising tool for regression analysis.

In this study, the robustness and predicted accuracy of LSM and GA was compared. Besides, different weights (equal and unequal weights) of each recording were used to compare the adaptability of the weights for practical application. Considering the hazard and energy radiation of an earthquake, the unequal weights of each recording are defined as functions of hypocentral distance. Moreover, the regression analysis of horizontal peak ground acceleration (PGA) attenuation model in southwest Taiwan was studied.

Methods of Regression Analysis

Least Squares Method

Consider y (the vector of observations or dependent variables) as a general nonlinear function of $\boldsymbol{\theta}$ (the vector of parameters to be estimated). Thus, y can be written as

$$\mathbf{y} = \mathbf{f}(\boldsymbol{\theta}) + \mathbf{e}$$

where $\mathbf{y} = [y_1 \quad y_2 \quad \cdots \quad y_n]^T$; $\boldsymbol{\theta} = [\theta_1 \quad \cdots \quad \theta_p]^T$; the vector of errors $\mathbf{e} = [e_1 \quad e_2 \quad \cdots \quad e_n]^T$; $\mathbf{f} = [f_1 \quad f_2 \quad \cdots \quad f_n]^T$ where f_i (i=1, 2, …, n) is a nonlinear function.

Several methods are available to solve this problem [6], such as the linearization method, steepest descent method, and the Levenberg-Marguardt method et al. The linearization method was used in this paper.

Genetic Algorithm

Recently, computational intelligence methods have been applied to a broad range of problems. Computational intelligence methods, such as neural network and genetic algorithm (GA), are highly adaptive methods originated from the laws of nature and biology. Unlike the mathematical methods, one of the important characteristics of computational intelligence methods is their effectiveness and robustness in coping with uncertainty, insufficient information, and noise. In this paper, GA is also employed to find the optimal solution.

GA is a search method based on Darwin’s theory of evolution and survival of the fittest. Darwin’s theory of nature selection is that “… any being, if it vary slightly in any manner profitable to itself … will have a better chance of surviving” [7]. His concept of survival affects “… not only the life of the individual, but success in leaving progeny.

Based on the concept of genetics, GA simulates the evolutionary process numerically. Analogous to genes in genetics, GA represents the parameters in a given problem by encoding them in a string. Instead of finding the optimum from a single point in traditional mathematical optimization methods, in GA a set of points, that is, a population of coded strings, is used to search for the optimal solution. Simple GA [4-5] consists of three basic operators: reproduction, crossover, and mutation.

In genetics, genes, which consist of alleles, constitute a chromosome. Similarly, in simple GA, encoded strings are composed of bits. The encoded string used in this study is represented by a string of unsigned binary integers. In the regression analysis of the attenuation form, the parameters to be encoded are coefficients in the attenuation form.

The method of string representation in simple GA was used in this paper, as shown is Fig. 1. In this method of string representation, the value of each parameter is represented by a sub-string of *k*-bit binary integers. In simple GA, a string is composed of sequentially connecting all the sub-strings. Fig. 2 shows the typical string representations in the simple GA using binary bits (each parameter is encoded in an 8-bit binary string in Fig. 2). The binary bits for the parameters are concatenated sequentially in simple GA.

To generate fitter string, GA reproduces the population according to their relative fitness; the strings with higher fitness have a better chance of passing their genes to the next generation. The proportional method is used to select the members of the next generation. A pair of parents is selected by a roulette wheel method. The slots on the perimeter of the roulette wheel are assigned to the individuals in proportion to their relative fitness functions. After reproduction a one-point crossover, with the probability of p_c, is performed to evolve new offspring. In addition, to inhabit premature convergence during the reproduction and crossover, mutation, with the probability of p_m, is implemented to maintain the genetic variability of the string.

Fig. 3 shows the essential elements of simple GA, which starts with a randomly generated population of individual possible solutions scattered over a pre-determined search space (the region in which the true answer is though to lie). The relative fitness of these individuals is determined and a stochastic selection process biased towards the fitter individuals is used to select parents for mating. In mating, attributes of the parents are mixed to form offspring which may or may not be fitter than one or both of the parents. In forming offspring, occasional random mutations can occur and also have the possibility of leading to a fitter individual. The process of selection, mating and mutation is repeated over a number of generations to allow the solution to evolve towards an optimum.

Attenuation model and Strong Motion Data

Since Campbell's attenuation form [2] can reasonably predict the characteristic of ground motion attenuation for data collected from Taiwan [8], it was applied in this study. Campbell's form is expressed as follows

$$Y(g) = b_1 e^{b_2 M_L} \left[R_h + b_4 e^{b_5 M_L} \right]^{-b_3} \tag{1}$$

where Y is peak ground acceleration (PGA) or the spectral acceleration, M_L is magnitude, and R_h is hypocentral distance.

Earthquake data of southwest Taiwan collected from Taiwan strong-motion seismic network (fig. 4) [9] were used in this study to develop the empirical PGA attenuation model. The database consists of 5323 recordings collected from 208 earthquake events of local magnitude $4.5 \le M_L \le 7.3$ and $R \le 300$km from 1993 to 2002. Fig. 5 gives the distribution of recordings with respect to magnitude and distance. Notably, near-field data of the Chi-Chi earthquake (M_L=7.3) at or very near the rupture surface were also adopted in this study. However, R_h in (1) is the shortest distance to the fault for the Chi-Chi earthquake data since the accompanied fault is about 80 km and the Earthquake can not be treated as a point source.

Results and Discussion

First, to compare the robustness and predicted accuracy of LSM and GA, LSM and GA with three different objective functions were used for regression analysis of earthquake data. The three objective functions are defined as follows in terms of the output error, which is a function of the difference between the measured and estimated PGA.

$$\sum_{p=1}^{P}(Y_{m,p}-Y_{e,p})^2/2 \tag{2}$$

$$\sum_{p=1}^{P}\frac{1}{\sqrt{R_{h,p}}}(Y_{m,p}-Y_{e,p})^2/2 \tag{3}$$

$$\sum_{p=1}^{P}\frac{1}{R_{h,p}}(Y_{m,p}-Y_{e,p})^2/2 \tag{4}$$

where $Y_{m,p}$ and $Y_{e,p}$ are the measured and estimated PGA of the pth instance, respectively; P is the total number of instance, and $R_{h,p}$ is the hypocentral distance of the pth instance. The weights of each recording in Eqs.(3) and (4) are $1/\sqrt{R_{h,p}}$ and $1/R_{h,p}$ respectively for considering the hazard and energy radiation of an earthquake while in Eq.(2) the weight of each recording is 1. Least squares methods with objective function defined as Eqs. (2), (3), and (4) were denoted as LSM1, LSM2, and LSM3, respectively. Methods of GA with objective function defined as Eqs. (2), (3), and (4) were denoted as GA1, GA2, and GA3, respectively. The optimum regression solution of a method of GA maximizes the fitness function. However, the optimum regression solutions of GA1, GA2, and GA3 minimize the objective functions defined as Eqs. (2), (3), and (4), respectively. Therefore, the fitness functions of GA1, GA2, and GA3 can be defined as a constant minus objective functions defined as Eqs. (2), (3), and (4), respectively. The number of iteration was set to be 5000 and the crossover probability (p_c) and mutation probability (p_m) were set to be 0.8 and 0.05, respectively for GA1, GA2, and GA3.

The predicted coefficients in Campbell's form were listed in Table 1. Note worthily, these coefficients were not found by LSM2 and LSM3, which reveals that GA is a much more robust optimization method than LSM. Table 2 lists the standard derivation of the natural logarithm of the peak ground acceleration, representing the dispersion about their respective median value, and objective function values of these methods. Results show that the standard derivation of the natural logarithm of PGA and the objective function value of LSM1 were smaller than those of GA1 (the objective function values of LSM1 and GA1 are almost the same). A smaller value of objective function means a more accurate prediction. Although predicted accuracies of LSM1 and GA1 were almost the same, the predicted accuracy of a GA method increases with increasing the number of iteration. The standard derivation of the natural logarithm of PGA of GA3 is smaller than that of GA1 and GA2, respectively. Although GA3 has a smaller standard derivation of the natural logarithm of PGA, the coefficients in Campbell's form predicted by GA3 is not the optimum solution that minimize standard derivation of the natural logarithm of PGA because the objective function of GA3, defined as Eq.(4), is not the natural logarithm of PGA.

Second, to find the optimum solution that minimizes standard derivation of the natural logarithm of PGA, methods of GA with the following three different objective functions were used for regression analysis of earthquake data.

$$\sum_{p=1}^{P}(\ln Y_{m,p} - \ln Y_{e,p})^2 / 2 \tag{5}$$

$$\sum_{p=1}^{P}\frac{1}{\sqrt{R_{h,p}}}(\ln Y_{m,p} - \ln Y_{e,p})^2 / 2 \tag{6}$$

$$\sum_{p=1}^{P}\frac{1}{R_{h,p}}(\ln Y_{m,p} - \ln Y_{e,p})^2 / 2 \tag{7}$$

Remarkably, the objective function of LSM can not be defined as Eqs. (5) to (7). Methods of GA with objective functions defined as Eqs. (5), (6), and (7) were denoted as GA4, GA5, and GA6, respectively. The predicted coefficients in Campbell's form are also listed in Table 1. Table 3 lists the standard derivation of the natural logarithm of PGA. Compare results listed in Table 3 with those listed in Table 2, the standard derivation of the natural logarithm of the PGA of GA4 is smaller than that of GA1, GA5 is smaller than GA2, and GA6 is smaller than GA3 as well. Results show that methods of GA with objective functions defined as Eqs. (5) to (7) are much more adequate than those with objective functions defined as Eqs. (2) to (4) to find the optimum regression solution that minimizes standard derivation of the natural logarithm of PGA. Besides, the standard derivation of the natural logarithm of PGA of GA5 is smaller than that of GA4 and GA6, respectively. Generally speaking, near-field damage is more serious than far-field damage when a large earthquake occurred; therefore, the optimum regression solution that minimizes standard derivation of near-field data should be found for practical application. Table 4 lists the standard derivation of the natural logarithm of near-field and far-field PGA data of GA4, GA5, and GA6. Results show that the standard derivation of the natural logarithm of near-field PGA data of GA5 and GA6 are almost the same and both of them are smaller than that of GA4. That is, GA5 and GA6 are more suitable for practical application than GA4. Fig. 6 shows the comparison of the earthquake data with the attenuation model predicted by GA4, GA5, and GA6. The study of Campbell (1981) developed a constrained PGA attenuation model in order for the predictions of PGA to be consistent with far-field data and the predictions of PGA at distances closer than 3 to 5 km from fault, where strong-motion data are extremely limited (many seismologists and geophysicists currently believe that at or very near the rupture surface peak acceleration become essentially independent of earthquake magnitude). This constrained model can be expressed as follows

$$Y(g) = b_1 e^{b_2 M_L}\left[R_h + b_4 e^{b_2/1.75 M_L}\right]^{-1.75} \tag{8}$$

Fig. 7 shows the comparison of the unconstrained and constrained PGA attenuation models predicted by GA4, GA5, and GA6 for magnitudes of 5, 6, and 7. Interestingly, the unconstrained and constrained PGA attenuation models predicted by GA5 for magnitudes of 6 are almost consistent. Besides, the unconstrained and constrained PGA attenuation models predicted by GA6 for magnitudes of 7 are almost consistent.

Conclusions

This study has compared the robustness and predicted accuracy of LSM and GA. The adaptability of different weights of each recording for practical application was also discussed. Moreover, the regression analysis of horizontal PGA attenuation model in southwest Taiwan was studied. The following conclusions are drawn:

1. GA is a much more robust optimization method than LSM since the coefficients in Campbell's form were not found for LSM2 and LSM3 (weighted least squares methods). Besides, the predicted accuracy of LSM1 and GA1 are almost the same in this study. However, the predicted accuracy of a GA method increases with the increasing of number of iteration.

2. The objective function of a regression method defined as a function of the difference between the measured and estimated PGA of the natural logarithm is much more adequate than that defined as a function of the difference between the measured and estimated PGA to find the optimum regression solution that minimizes standard derivation of the natural logarithm of PGA. Notably, the objective function of a GA method is easy to be defined as a function of the difference between the measured and estimated PGA of the natural logarithm. However, the objective function of LSM only can be defined as a function of the difference between the measured and estimated PGA.

3. A regression method that minimizes standard derivation of near-field data is useful for practical application. The standard derivation of the natural logarithm of near-field PGA data of GA5 and GA6 are almost the same and both of them are smaller than that of GA4. That is, GA5 and GA6 are more suitable for practical application than GA4.

Acknowledgements

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Table 1. The predicted coefficients in Campbell’s form

Method	Regression coefficients				
	b_1	b_2	b_3	b_4	b_5
LSM1	0.0397	3.3146	4.0560	0.7320	0.7867
LSM2	--	--	--	--	--
LSM3	--	--	--	--	--
GA1	0.1000	3.4770	0.9871	0.7577	4.3725
GA2	0.0929	2.4235	1.0945	0.6698	3.2544
GA3	0.0687	1.0359	1.0958	0.4513	1.6485
GA4	0.0095	1.2143	1.5632	0.6575	0.5282
GA5	0.01269	1.1678	1.4948	0.7705	0.4697
GA6	0.0188	1.2019	1.6211	0.9482	0.4745

Table 2. The standard derivation of the natural logarithm of the horizontal PGA $\sigma_{\ln(err)}$ for NLSM1, NLSM2, NLSM3, GA1, GA2, and GA3

Method	$\sigma_{\ln(err)}$	Value of objective function
LSM1	0.8285	3.2932
LSM2	--	--
LSM3	--	--
GA1	0.8370	3.2954
GA2	0.7509	1.0657
GA3	0.7076	0.6149

Table 3. The standard derivation of the natural logarithm of the horizontal PGA $\sigma_{\ln(err)}$ for GA4, GA5, and GA6

Method	$\sigma_{\ln(err)}$
GA4	0.7459
GA5	0.6370
GA6	0.6441

Table 4. The standard derivation of the natural logarithm of the horizontal PGA $\sigma_{\ln(err)}$

Method	R_h<=50 km (near-field)	R_h>50 km (far-field)
GA4	0.7717	0.7272
GA5	0.7140	0.5752
GA6	0.7141	0.5886

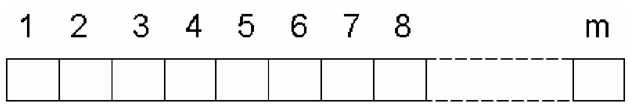


Fig. 1. String representation in simple GA

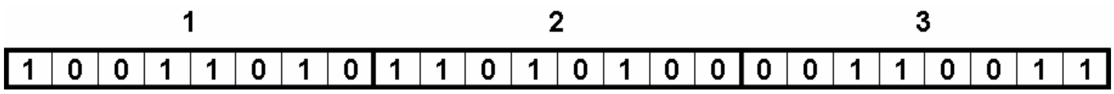


Fig. 2. Example of string representation scheme in simple GA

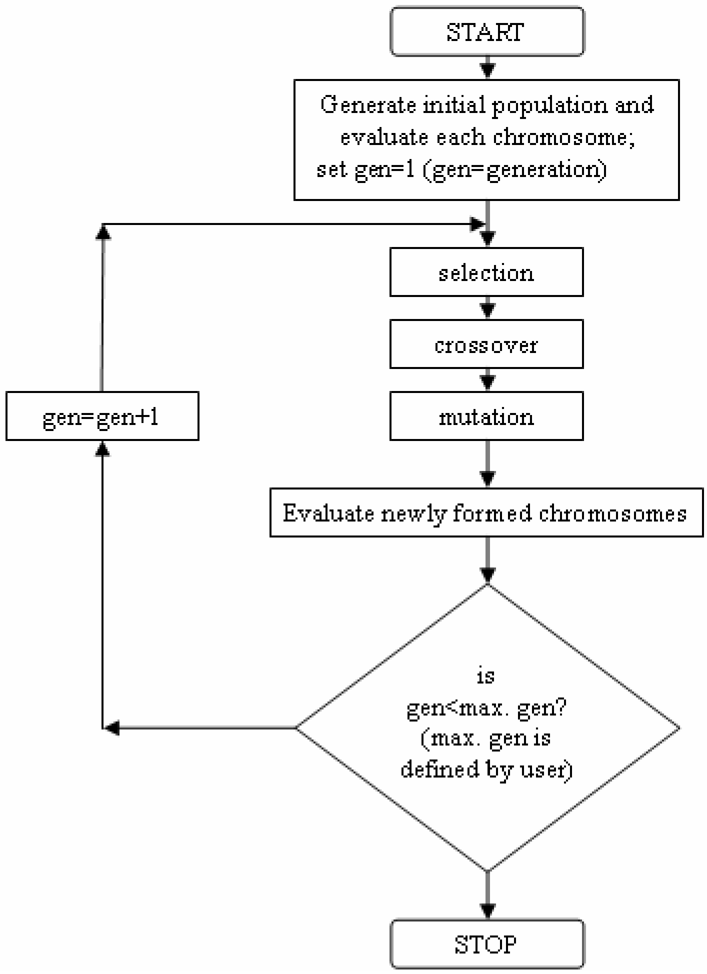


Fig. 3. Elements of simple GA

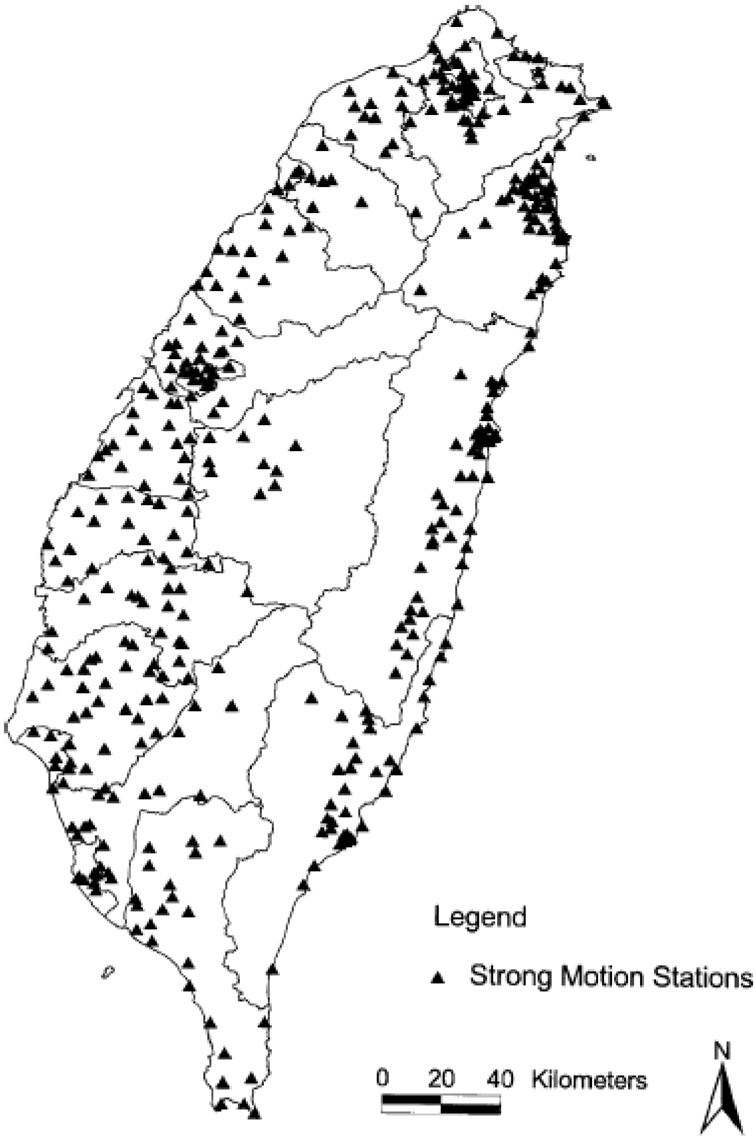


Fig. 4. Free-field strong-motion stations on the island of Taiwan.

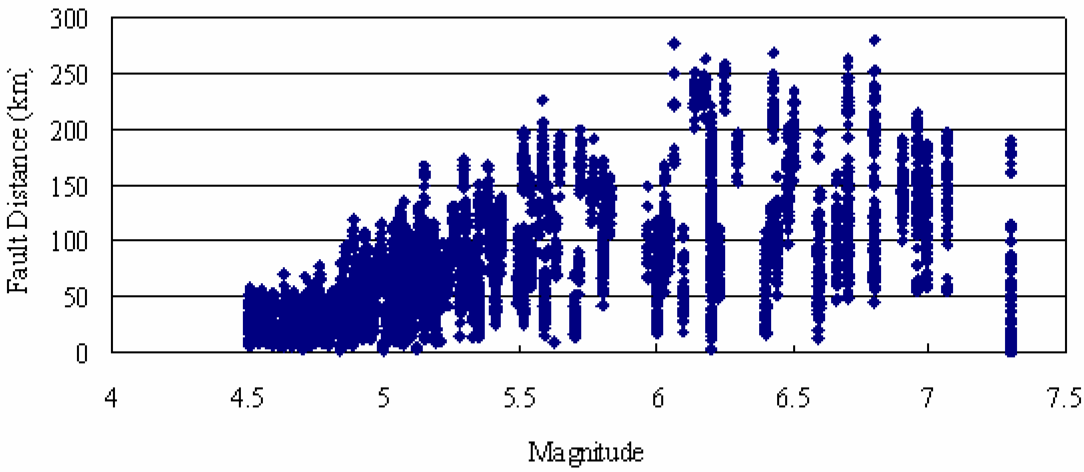
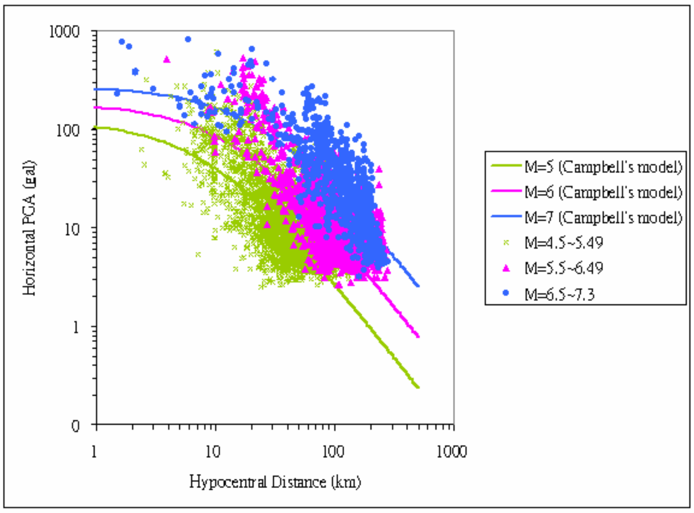
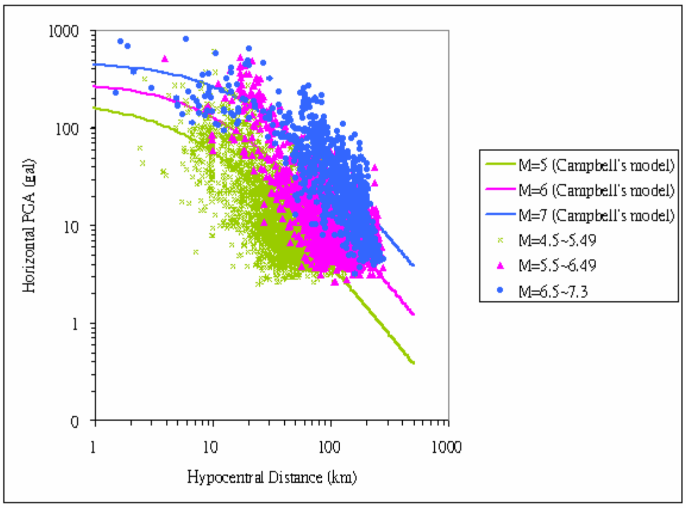


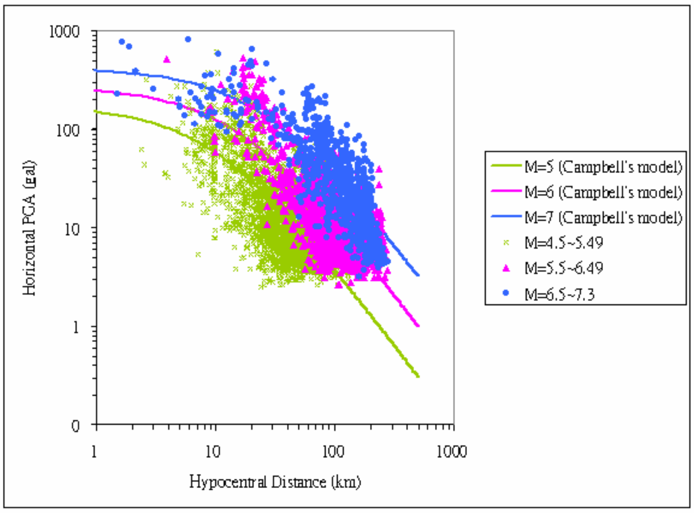
Fig. 5. The distribution of strong-motion recordings with respect to magnitude and distance.



(a)

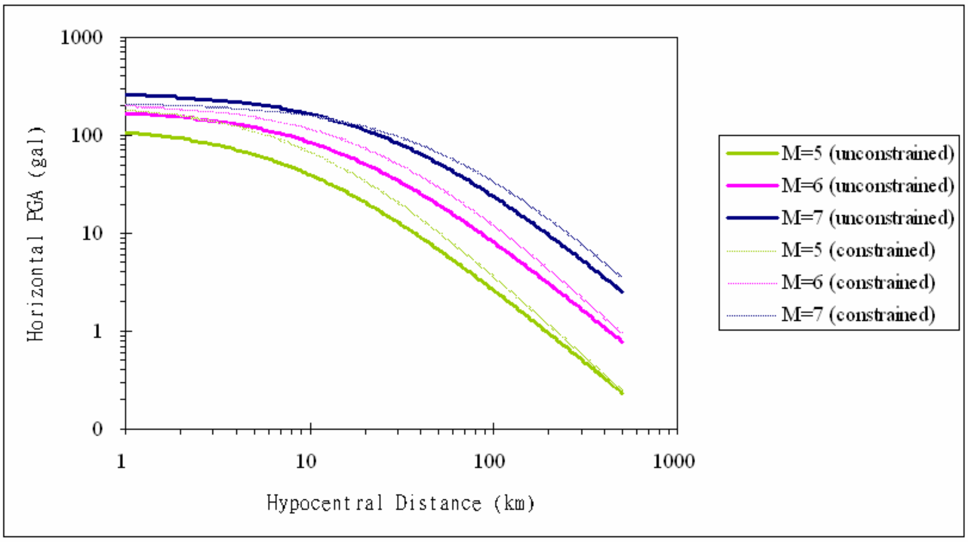


(b)

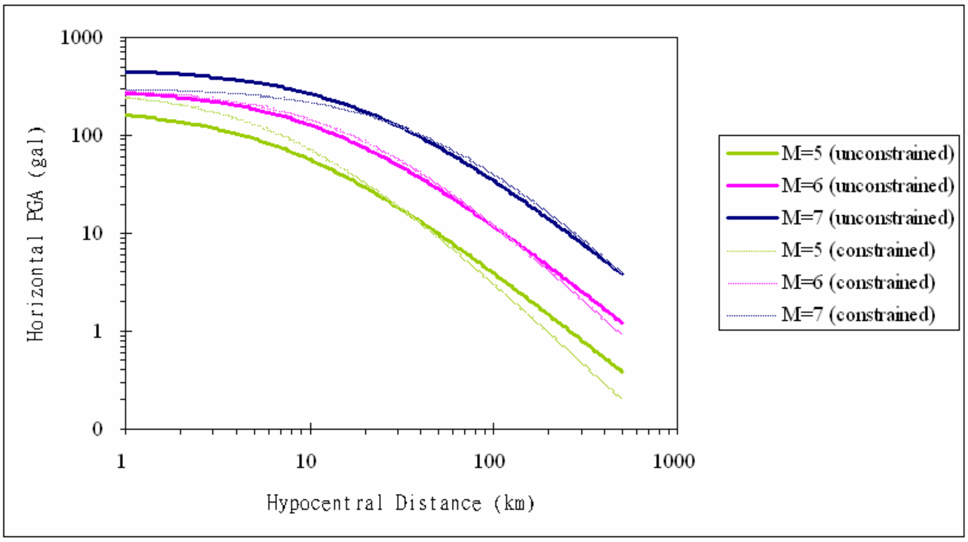


(c)

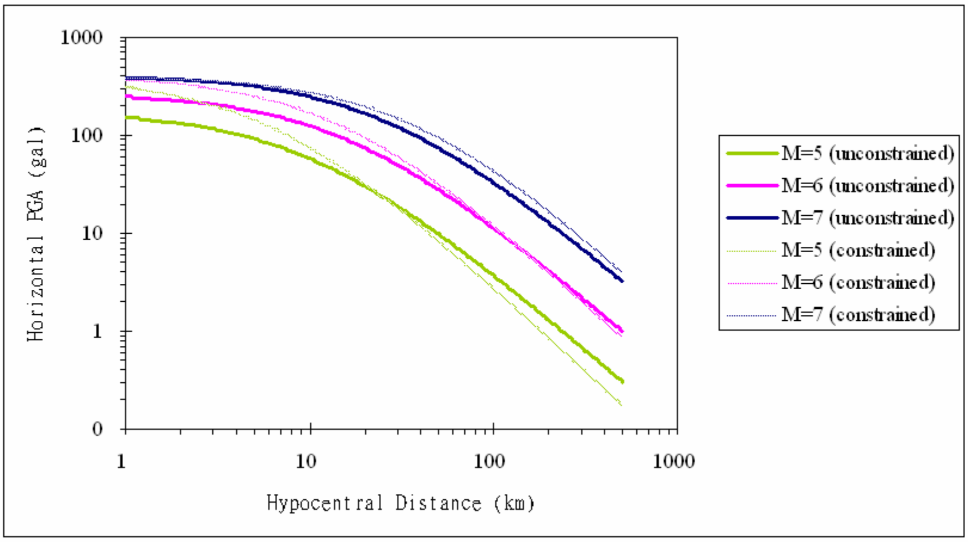
Fig. 6. The comparison of the earthquake data with the attenuation form predicted by (a) GA4, (b)GA5, (c) GA6.



(a)



(b)



(c)

Fig. 7. The comparison of the unconstrained and constrained ground motion model for magnitudes of 5, 6, and 7 (a) GA4 (b) GA5 (c) GA6

出席國際學術會議心得報告

計畫編號	NSC 96-2119-M-041-001-
計畫名稱	譜震度與活斷層區應變分佈之研究
出國人員姓名 服務機關及職稱	葉永田；嘉南藥理科技大學產業安全衛生與防災研究所特聘教授
會議時間地點	2008 年 7 月 28 日到 8 月 1 日於澳洲凱恩斯**(Cairns)**
會議名稱	2008 西太平洋地球物理會議(2008WPGM)
發表論文題目	1. A Study on Attenuation of Peak Ground Acceleration in Southwest Taiwan. 2. Fault Activity Observation Using Gladwin Tensor Strainmeter in Western Taiwan.

一、參加會議經過

「2008 年西太平洋地球物理會議」是由美國地球物理聯會以及數個地球科學組織主辦。本人在國科會的經費資助下，前往澳洲凱恩斯參加會議並發表論文。

此次大會共有：共同議題（Union）、行星科學（Planetary Science）及 10 個地球科學（Earth Science）次學門等的 12 個議程。其中地震學門（Seismology）的議題，有五個子題，分別為：(1) Earthquake Observations and Studies on Active Faults; (2) Seismic Slip Models and Seismic Wave Propagation; (3) Seismic Studies in the Regions of Taiwan; (4) Seismic Tectonics, Assessment, Predictions, and Surface Waves; (5) General Seismology。此五個子題，共有 32 篇文章；參與第 3 個子題 ”Seismic Studies in the Regions of Taiwan”，的台灣學者，針對台灣的地震研究與發展現況發表 6 篇的文章，參與討論的它國學者也提出不少有意義的問題，這有助於促進台灣與各國學者的學術交流；本人在此議題下發表兩篇論文：1) A Study on Attenuation of Peak Ground Acceleration in Southwest Taiwan；2) Fault Activity Observation Using Gladwin Tensor Strainmeter in Western Taiwan。此外，在會議期間本人亦參加一部份其他地震學門、大地測量學門（Geodesy）和大地構造學門（Tectonophysics）議題的論文發表會及壁報展示，並參與討論。

二、與會心得

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Cite abstracts as **Author(s) (2008), Title, *Eos Trans. AGU*, *89*(23), West. Pac. Geophys. Meet. Suppl., Abstract xxxxx-xx**

Your query was:
yeh and sc=seismology

HR: 09:30h
AN: S51A-04
TI: A Study on Attenuation of Peak Ground Acceleration in Southwest Taiwan

AU: *Kao, C
EM: *chingyun@mail.chna.edu.tw*
AF: *Institute of Industrial Safety and Disaster Prevention, Chia Nan University of Pharmacy & Science, No. 60, Sec. 1, Erh-Jen Rd., Tainan, 71710, Taiwan*
AU: Yeh, Y
EM: *ytyehchna@mail.chna.edu.tw*
AF: *Institute of Industrial Safety and Disaster Prevention, Chia Nan University of Pharmacy & Science, No. 60, Sec. 1, Erh-Jen Rd., Tainan, 71710, Taiwan*
AU: Chung, J
EM: *jkchung@cyu.edu.tw*
AF: *General Education Center, Ching Yun University, No. 229, Chien-Hsin Rd., Jung-Li, 320, Taiwan*

AB: Taiwan is an area of high seismicity and many damaging earthquakes took place there in the last century. Therefore, earthquake hazard mitigation is an important issue in Taiwan. In engineering applications, the development of an attenuation relationship in a seismic hazard analysis is a useful way for earthquake hazard mitigation. The optimal solution of parameters in nonlinear attenuation of peak ground acceleration model can be found by least square methods (LS method) for simplicity. However, it is not reasonable to use unweighted regression analysis in which each recording carried an equal weight due to nonuniform distribution of data with respect to distance. Some Researchers used weighted least square method (WLS method) in an attempt to compensate for the nonuniform distribution of data with respect to distance. Besides, it is difficult to find the optimal solution of parameters in attenuation model using traditional mathematical methods (both LS and WLS methods) because of its nonlinearity. Unlike the traditional mathematical methods, genetic algorithm (GA) uses multiple points to search for the global optimal solution rather than a single point in search of the local optimal solution in the traditional gradient based optimization method. In this study, LS method, WLS method, and genetic algorithm (GA) are employed as a nonlinear regression method to find the optimal solution of parameters in attenuation models. Unweighted regression analysis is compared with weighted regression analysis (considering the hazard and energy radiation of an earthquake, the weight of each recording is defined as a function of hypocentral distance). Earthquake data of southwest Taiwan collected from Taiwan Strong Motion Instrumentation Program (TSMIP) system were used in this study to develop the empirical attenuation form. The database consists of 5323 recordings collected from 208 earthquake events of magnitude between 4.5 and 7.3 and hypocentral distance less than and equal 300km from 1993 to 2002.

DE: 7212 Earthquake ground motions and engineering seismology
SC: Seismology [S]
MN: 2008 Western Pacific Geophysics Meeting

New Search

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yeh and sc=seismology

HR: 10:10h
AN: S51A-06
TI: Fault Activity Observation Using Gladwin Tensor Strainmeter in Western Taiwan

AU: *Yeh, Y
EM: *ytyehchna@mail.chna.edu.tw*
AF: *Institute of Occupational Safety and Hazard Mitigation, Chia Nan Univ. of Pharmacy & Science, 60, sec.1, Er-Jen Road, Jen-Te, Tainan, 717, Taiwan*
AU: Liu, T
EM: *liutk@ntu.edu.tw*
AF: *Institute of Geological Science, National Taiwan Univ., 1, Sec.4, Roosevelt Road, Taipei, 106, Taiwan*
AU: Lee, M
EM: *minlee@ntu.edu.tw*
AF: *Institute of Occupational Safety and Hazard Mitigation, Chia Nan Univ. of Pharmacy & Science, 60, sec.1, Er-Jen Road, Jen-Te, Tainan, 717, Taiwan*
AU: Gladwin, M
EM: *mike@gtsmtechnologies.com*
AF: *GTSM Technology Inc., Brisbane, Queensland, 4069, Australia*

AB: There are over 40 documented active faults distributed mainly along either western foothill or eastern coastal range of Taiwan. Many disastrous earthquakes were caused by these faults in history in which the most recent case is the Chichi event caused by the reactivated Chelongpu fault on Sep. 21, 1999. A project of fault activity observation using 3-component Gladwin Tensor Strainmeter was initiated later by the Central Geological Survey of Taiwan. These instruments are installed at a depth of approximately 200 meters at 12 sites of 4 clusters to provide 3 component strain data on both long term crustal strain accumulation and Coseismic strain offsets useful for constraining earthquake source mechanisms. All sites are performing well and have already captured significant aseismic and seismic data on local and regional events. Residual data are recovered from the raw data by extracting one or two least squares fitted exponential(s) plus one linear function which describe the processes of curing of the grout and recovery of the borehole, after drilling and installation disturbance of the virgin stress field. One areal strain and two shear strains then can be resolved from residuals of 3 components. The continuous change of two shear strain is most informative in active fault monitoring. The long-term stability of the instrument in the field is the most concerned at present, since siting of the borehole on best estimates of the geology and hydrology is actually more difficulty than production of good borehole-type straimeter. In the laboratory, the GTSM strainmeter has long-term stability of better than one nanostrain per year if the distressing is properly performed. In the field, one example of installation of a standard instrument in a relatively arid and stable tectonic region in Australia has demonstrated that a long-term stability of much better than 100 nanostrain per year. However, there is evident that dilatometers in Iceland have been strongly influenced by aquifer pore pressure change. If the rock surrounding the borehole is inhomogeneous and anisotropic, the pore pressure change effect in the shear strain components could also be significant. Another meteorological effect to be considered is the influence of atmospheric pressure on measured strain. Effects from change of either pore pressure or atmospheric pressure must be understood if the tectonic strain is to be understood. There have been 29 recorded typhoons attacked or swept this island since the first GTSM strainmeter was deployed in the end of 2003. Typhoons were usually accompanied by heavy rainfall and significant

atmospheric depression which had left their effects on the continuously recorded strain data at each site. The atmospheric admittance of GTSM strainmeter generally is documented in about 0.5 nanostrain per millibar. Groundwater level change initiated by rainfall seems to be the major cause that is responsible for the observed strain anomalies. Very small changes of temperature in wall rock induced by infiltrated precipitation may produce quite large thermo-elastic strain response. Therefore, this program has deployed a piezometer at tens of meters above the co-site strainmeter at last nine sites, this will be able to use the pore pressure measurements to define repeatable strain responses to pore pressure change that can be used to correct the strain data.

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DE: 8118 Dynamics and mechanics of faulting (8004)
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出席國際學術會議心得報告

計畫編號	NSC 96-2119-M-041-001-
計畫名稱	譜震度與活斷層區應變分佈之研究
出國人員姓名 服務機關及職稱	葉永田；嘉南藥理科技大學產業安全衛生與防災研究所特聘教授
會議時間地點	2008 年 7 月 28 日到 8 月 1 日於澳洲凱恩斯**(Cairns)**
會議名稱	2008 西太平洋地球物理會議(2008WPGM)
發表論文題目	1. A Study on Attenuation of Peak Ground Acceleration in Southwest Taiwan. 2. Fault Activity Observation Using Gladwin Tensor Strainmeter in Western Taiwan.

一、參加會議經過

「2008 年西太平洋地球物理會議」是由美國地球物理聯會以及數個地球科學組織主辦。本人在國科會的經費資助下，前往澳洲凱恩斯參加會議並發表論文。

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AU: Yeh, Y
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AF: *Institute of Occupational Safety and Hazard Mitigation, Chia Nan Univ. of Pharmacy & Science, 60, sec.1, Er-Jen Road, Jen-Te, Tainan, 717, Taiwan*
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