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Department of Mathematics
Faculty of Mathematics and Natural Sciences,
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ICMSA 2009

June 9-11, 2009 The Hills Hotel Bukittinggi, Indonesia

PROCEEDING

The 5th IMT - GT International Conference on Mathematics, Statistics and Their Applications

ICMSA 2009

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I Made Arnawa, Muhafzan,
Maiyastri, Susila Bahri

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Preface

First of all, I would like to say welcome to Bukittinggi, Indonesia to all of you. It is an honour for us to host this conference. We are very happy and proud because the participants of this conference come from many countries; we have participants from Libya, Japan, Qatar, India, Malaysia, Singapore, Thailand, Iran, and many more.

Ladies and gentlemen, according to constructivism theory, mathematics comes out as a result of social construction; that's why, the outcomes of our researches in mathematics, like theorem or formula of mathematics, should be communicated in a scientific forum such as seminar or conference. Through this kind of seminar or conference, we could refine the existing theorems or we could get new ideas to produce a new one. Seminar or conference which is held annually enables us to continually develop the science of mathematics until the end of the time.

That's way, in this two-day conference, we are going to discuss around 250 papers coming from diverse aspects of mathematics ranging from analysis, applied mathematics, statistics, algebra, Computational Mathematics, mathematics education, and other related topics.

For all of us here, I would like to convey my endless appreciation and gratitude for your participation in this conference.

Thank you very much

Dr. I Made Arnawa
Chairman of the Conference

Message from Rector Andalas University

It gives me great pleasure to extend my sincere and warm welcome to the participants of the 5th International Conference on Mathematics Statistics and Application (The IMT GT's 5th ICMSA 2009) - A Joint Scientific Program organized by Universities over Indonesia, Malaysia and Thailand Growth Triangle Region. On behalf of Andalas University, let me welcome all of you to the conference in Bukittinggi, West Sumatra Province, the land of Minang kabau.

We believe that from this scientific meeting, all of participants will have time to discuss and exchange ideas, findings, creating new networking as well as strengthen the existing collaboration in the respective fields of expertise. In the century in which the information is spreading in a tremendous speed and globalization is a trend, Andalas University must prepare for the tough competition that lay a head. One way to succeed is by initiating and developing collaborative work with many partners from all over the world. Through the collaboration in this conference we can improve the quality of our researches as well as teaching and learning process in mathematics and to achieve standards and requirements applied in many developed countries. I strongly believe that this conference is and extraordinary testimony to our capacity building at international, regional and local level.

I would like to express my deep gratitude to International Scientific Committee of who has honored the Mathematics Department, Faculty of Mathematics and Natural Sciences, Andalas University to host this prestigious conference. This is a very special opportunity for us to be involved in a regional community of knowledgeable scientist in the field of mathematics, statistics and their applications. I would also like to extend my gratitude to keynote speakers, participants, and organizer of this conference for their contribution to this event. My special thank is also rendered to the local government of West Sumatra for various supports and facilities.

Finally I wish all participants a fruitful deliberation at the conference. I also wish all participants and accompanying spouses a pleasant and enjoyable stay in Bukittinggi City, West Sumatra.

Prof. Dr. Ir. Musliar Kasim, MS
Rector

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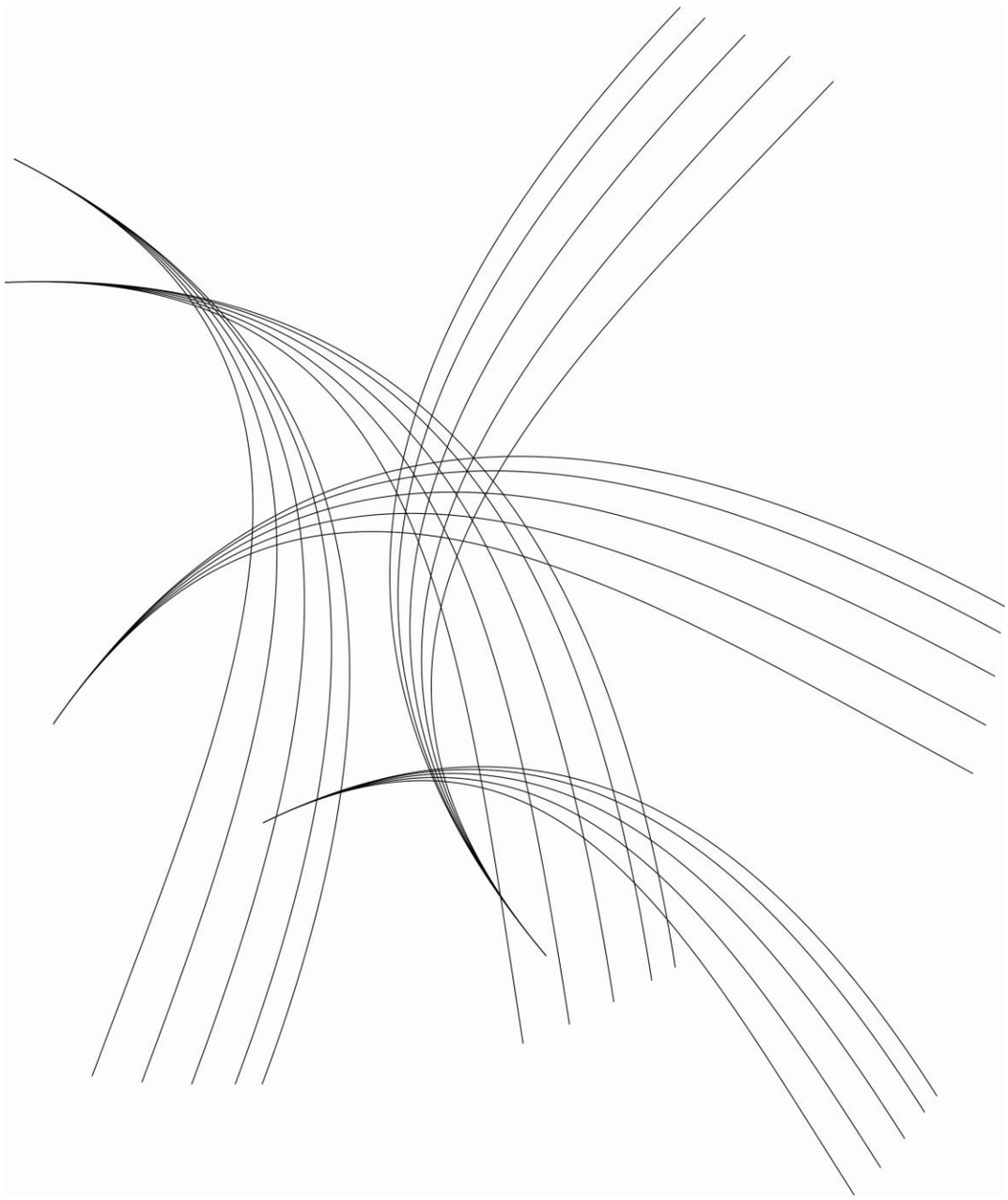

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Recurrence Time Modeling for Earthquake Prediction

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Abstract

In this study, statistical approach is used for predicting the probability of occurrence of earthquake using recurrence and elapse time. The data are from 1907 to 2008, in the area between 0^0 - 5^0 N and 90^0 – 110^0 E, with magnitude ≥ 6.0 Richter scale, which include tsunami earthquake that occurred on Dec 26, 2004. Four reccurrence models (i.e. Gamma, Exponential, Log-normal, and Weibull) are examined for determining the best one that represents earthquake data. The maximum likelihood method is better parameter estimation than least squares and moment, because it has a lower Mean Squared Error. Based on Akaike and Bayesian Information Criterion, Weibull is better fitting than the others using Kolmogorov-Smirnov, Anderson-Darling, and Chi-Square test statistic. Cumulative distribution function of Weibull is used to predict earthquakes that will be occurred. The methods of maximum likelihood and moments are similar, least squares has a lower prediction. In general, for zero elapse time, the occurrence probability are higher than non-zero elapse time.

Keywords: earthquake prediction, parameter estimation, recurrence time.

1. Introduction

A large earthquake caused heavy damage and loss of life. Statistical studies of earthquake occurrences have frequently been carried out since the early years of seismology. A number candidate recurrence models have been proposed for computation of conditional probabilistic of future earthquake, including Double exponential, Gaussian, Weibull, Log-normal, Pareto, and Gamma [6]. The challenge lies in determining the appropriate distribution for given data

Some distribution models have been published. Four recurrence models have been compared (i.e. Exponential, Log-normal, Gamma, and Weibull) utilizing the data in fifteen circular area on Taiwan. Gamma model using moments method gives a better fitting to the data than other recurrence models [4]. The other study has also been carried out to compare eleven models (i.e. Beta, Erlang, Exponential, Gamma, Log-logistic, Log-normal, Pearson V, Pearson VI, Tringular, Uniform, and Weibull) using the data in NAFZ (Northern Anatolian Fault Zone), Turkey. They obtained a reasonably good fit to a Weibull istribution [6].

A zero elapse time is developed to construct a prediction model. In this study, we will carry out for earthquake prediction on the set data that elapse time is considered. The data are from Meteorological and Geophysical Agency of Indonesia, from 1907 to 2008 in the area between 0^0 – 5^0 N and 90^0 – 110^0 E, with magnitude ≥ 6.0 Richter scale , which includes tsunami earthquake that occurred on Des 26, 2004 (Figure 1). The candidate recurrence models which fitted are Exponential, Log-normal, Gamma, and Weibull. The comparison are made using Kolmogorov-Smirnov (*KS*), Anderson-Darling (*AD*), and Chi-square (χ^2) test statistics [2]. Models are selected using *AIC* (Akakike Information Criterion) and *BIC* (Bayesian Informaton Criterion) values. A model with a lower value of AIC and BIC is considered to be a better model [5]. The parameter estimations of these models used three method, namely, maximum likelihood (*MLE*), least squares (*LS*), and moments (MM) [1,3]. The method with a lower Mean Squared Error (*MSE*) is better than the others [1]. Earthquake prediction based on these three estimation methods have been calculated for different time periods.

2. Results and Discussion

Using the method of maximum likelihood, parameter estimations of each distribution are *Exp*($\hat{\theta}$ = 1.014), *LN*($\hat{\mu}$ = -1.613, $\hat{\sigma}$ = 2.488), *G*($\hat{\alpha}$ = 0.4039, $\hat{\beta}$ = 2.510), and *W*($\hat{\gamma}$ = 0.5436, $\hat{\eta}$ = 0.5877). Hence, determination of the distribution which fits the earthquake data best, the test statistics, summarized briefly in Table 1.

Table 1. Goodness of Fit Results

Distribution	KS/p-value	AD/p-value	$\chi^2(\upsilon = 12)$/p-value
Exponential	0.2597/0	19.174/0.003	82/0
Log-normal	0.1188/0.1186	2.538/0.005	24.02/0.0202
Gamma	0.0729/0.6627	0.635/0.119	11.8/0.4619
Weibull	0.0656/0.782	0.400/0.250	11.28/0.5051

By taking significant level (α) = 5 %, the test statistics show that Gamma and Weibull are reasonable to the data (Table 1). For getting the best one of fit to the data, we compute the *AIC* and *BIC* values of them. *AIC* value of Gamma and Weibull are 124.1494 and 122.5796, and *BIC* are 129.3598 and 127.79,

respectively. Because *AIC* and *BIC* values of Weibull has a lower than Gamma, Weibull is selected as a recurrence model. In making earthquake predictions, cumulative distribution function (*CDF*) of Weibull is given below [1]:

$$G_T(t) = 1 - \exp\left\{\left(\frac{u}{\eta}\right)^{\gamma} - \left[\frac{(u+t)}{\eta}\right]^{\gamma}\right\} \qquad (1)$$

Where: $T = X - u$, X is a random variable of recurrence time, T and u are the waiting and elapse time, γ and $\boldsymbol{\eta}$ are the shape and the scale parameters (in year), $G_T(t)$ is the probability of earthquake occurrence before $u + t$, known until u has never occurred. Further, computation of parameter estimations using by *LS*, and *MM* are $W(\hat{\gamma} = 0.4817, \hat{\eta} = 0.6372)$, and $W(\hat{\gamma} = 0.5309, \hat{\eta} = 0.5628)$, respectively. Substitution for u = 0, 1000, 3000 and $u + t$ = 5846 days, the plots of the three methods of parameter estimation, *MLE* (red dash line style), *LS* (blue line style), and *MM* (black dot line style) into (1) are shown in Figure 2. By taking $u + t$ = 4000 and u = 0 day, the probability of earthquake occurrence are 0.9926, 0.9805, and 0.9921 for *MLE*, *LS*, and *MM*, respectively. If we take u = 1000 days, the probability before 4000 days decrease to 0.9255, 0.8531, and 0.9195. And also for u = 3000 days, the probability become 0.5085, 0.3992, and 0.4959. Therefore, as $T \to 0, G_T(t) \to 0$, and as $u \to \infty, G_T(t) \to 1$. Computation of *MSE* of *MLE*, *LS*, and *MM* are 5.92×10^{-2}, 11.56×10^{-2}, and 8.13×10^{-2}, respectively. Hence, it can be concluded that *MLE* is better parameter estimation than the others.

3. Conclusions

Four recurrence models are examined for determining the one that represents earthquake data. *AIC* and *BIC* suggest the Weibull model is the correct distribution for the given data. The cumulative distribution function is used to predict the earthquake occurrences, and can be calculated from formula (1). As expected, for elapse time approach infinity, the occurrence probabilities tend to 1.

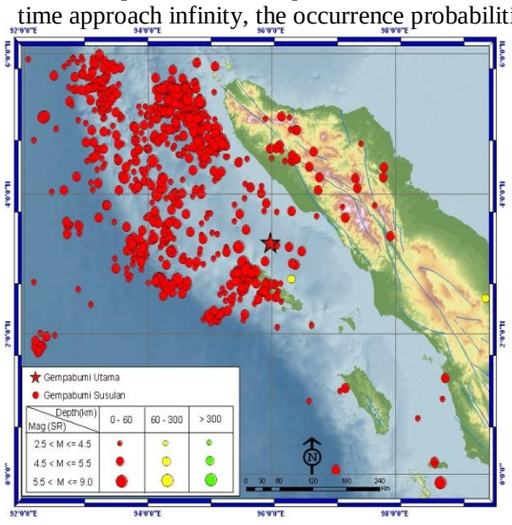

Figure 1. The area of investigation

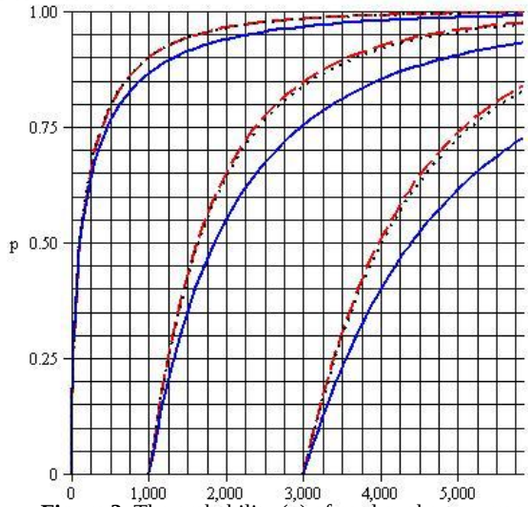

Figure 2. The probability (p) of earthquake occurrence

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