DETERMINATION OF CONCENTRATION OF EARTHQUAKES CLUSTERING

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ABSTRACT

Earthquakes arrive without previous warning and can destroy a whole city in a few seconds, causing numerous deaths and economical losses Nowadays, a great effort is being made to develop techniques that forecast these unpredictable natural disasters by using statistical methods

In most studies of earthquake spatial distribution prediction are used statistical estimation of the fractal spatial dimension Earthquake spatial distribution is very complex because of the depth inhomogeneity, the fractal character of spatial pattern, and various hypocenter location errors all make model parameterization difficult and create various biases in estimating parameters

However, these publications insufficiently consider the systematic effects which influenced estimation of the fractal or scaling dimensions of earthquakes Some of the above publications estimated several effects by using simulation catalogs; such simulations are insufficient for fully understanding various geometrical distributions

In this paper, Copulas methods are used for pattern recognition of earthquake distribution The study of copulas and their applications in statistics is a rather modern phenomenon

Copulas are of interest to statisticians for two main reasons: Firstly, as a way of studying scale-free measures of dependence; and secondly, as a starting point for statistical seismicity analysis with a view to simulation earthquake data catalogue

INTRODUCTION

Pattern recognition of Earthquakes distribution and aftershocks clustering is an important and complicated issue in seismology for investigation of the dynamics of earthquakes sources requires the use of advanced statistical methods

Pattern recognition technique has been shown to elegantly and powerfully realize solutions to problems in Seismology and earthquake prediction A few applications of advanced statistical methods to seismology have been carried out For example Alexander et al (1992), Leach et al (1993), Tsvang et al (1993), Taylor et al (1989), Allameh Zadeh and Nassery (1999) have applied artificial neural networks to the explosion seismology for discriminating natural earthquakes versus explosions

The goal of pattern recognition in seismology is to identify earthquake prone area using standard geological data Gelfand makes previous applications of pattern recognition to earthquake locations in 1972, for strictly predictive purposes in central Asia and Anatolia and in California A pattern is a suite of traits that characterizes a group of objects, such as earthquake epicenters, and distinguishes this group of objects from another group, such as places that will not be epicenters The other methodology is developed by IIEPTandMG that has been applied to many seismic regions of the world for the identification of seismogenic nodes (Gorshkov et al 1991;2009; Gavishiani et al 1988) Recent earthquakes in each of the regions studied have proved the reliability of the results obtained As Gorshkov et al (2009) demonstrated, 90% of the post-publication events with relevant magnitudes occurred at the nodes, and 84% of the post-publication earthquakes occurred at the nodes recognized as prone to strong earthquakes

Murat and Rudman (1992), Wang (1992), Wang and Mendel (1992), McCormack et al (1993), and Roth and Tarantola (1994) have applied artificial neural networks to reflection and refraction seismic studies Katz and Aki (1992) and Allamehzadeh and Mokhtari (2003) have developed an approach to earthquake prediction using neural network techniques Serono and Patnaik (1993) have applied neural networks to phase identification at three-component stations Tung et al (1994) have applied neural networks to predict the spatial distribution of the Modified Mercalli intensity for the California area Dai and Macbeth (1995) have performed a study to test the ability of an ANN to detect and pick local seismic arrivals In many respects the above lists summarizes the features of conventional earth science data, and are the main reasons for the increasing popularity of advanced statistical techniques in geosciences

In this paper an approach is presented to predict the concentration and forecasting large earthquakes in Alborz area in Iran The method is based on Copulas that have attracted much attention in spatial statistics over the past few years More recently copula function have been used in other fields such as climate, oceanography, hydrology, geodesy, reliability, evolutionary computation and engineering By using copula theory, a joint distribution can be built with a copula function and, possibly, several different marginal distributions Copula theory has been used also for modeling multivariate distributions (Smith 2003; Nelsen 2006)

They are used as a flexible alternative to traditional methods for non- Gaussian spatial modeling and interpolation This methodology show how it can also be predicted aftershocks distribution in a Bayesian framework by assigning priors to all model parameters The Gaussian spatial copula model is equivalent to trans-Gaussian kriging with transformation function A restriction of the Gaussian copula is that it models not only a symmetric but even a radially symmetric dependence, where high and low quartiles have equal dependence properties Experimental results show that the proposed models are superior to predict and identify seismic risk at high seismicity areas is very important work to assess the seismic hazard

we have design a type of Gaussian spatial copula model that its ability is to discover seismic patterns (Pattern Recognition) such as doughnuts patterns before large earthquakes (eg Mogi, 1985; Turcotte, 1991; Sholez, 2002; Kanamori, 2003) and also can predict the trend of earthquake aftershock's pattern in nonlinear systems such as earth

In this paper, we used a copula function that links (couples) the univariate marginal distributions to the joint distribution (Figure 1)

The word copula originates from the Latin meaning link, chain, union In statistical literature, according to the seminal result in the copula's theory stated by Fermanian J-D and M Wegkamp in 2009, a copula is a function that connects multivariate distribution function to its univariate marginal distributions One of the primary applications of copulas is in simulation and Monte Carlo studies In this paper, we will address the problem of generating earthquake catalog from a specified joint distribution Such samples can then be used to study mathematical models of real-world earth systems

There are a variety of procedures used to generate observations (x,y) of a pair or random variables (X,Y) with a joint distribution function H We will focus on using the copula as a tool By virtue of Sklar's theorem, we need only generate a pair (u,v) of observations of uniform (0,1) random variables (U,V) whose joint distribution function is C, the copula of X and Y, and then transform those uniform variates via the algorithm such as the one in the preceding paragraph One procedure for generating such of a pair (u,v) of uniform (0,1) variates is the conditional distribution method (Figure 2)

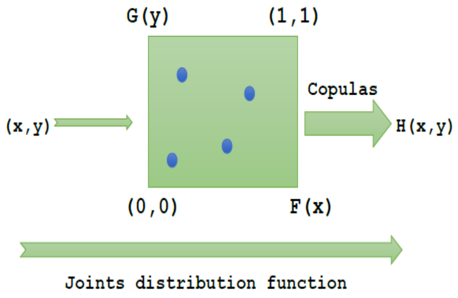

Figure 1. observations (x,y) of a pair or random variables (X,Y) with a joint distribution function H

The main purpose and contribution of the copula function is the separation of the joint dependency and the marginal behavior

If we have a collection of copulas, then, as a consequence of Sklar’s theorem, we automatically have a collection of bivariate or multivariate distributions with whatever marginal distributions we desire Clearly this can be useful in modeling and simulation Furthermore, by virtue of Theorem, the nonparametric nature of the dependence between two random variables is expressed by the copula Thus the study of concepts and measures of nonparametric dependence is a study of properties of copulas For this study, it is advantageous to have a variety of copulas at our disposal

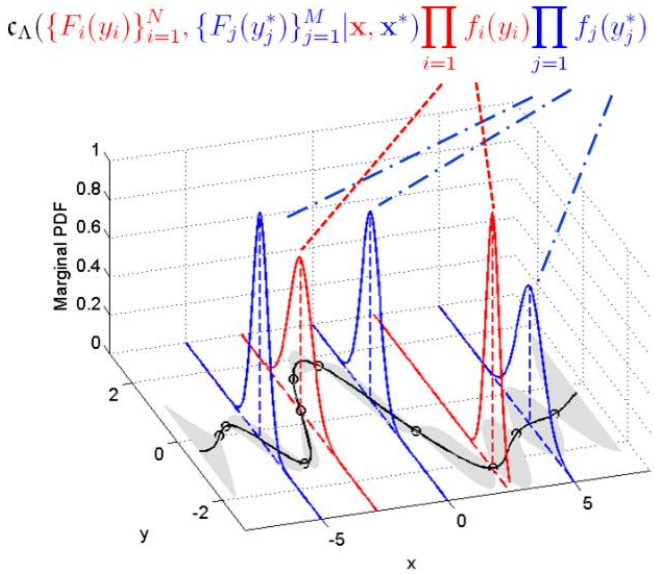

Figure 2. A pictorial illustration of a univariate KCP A prototypical univariate process is drawn on the The constituent parts of a KCP are shown in the vertical dimension: (1) the marginal distribution at each point in the input space x (eg time) from which observations are drawn at that particular input; (2) the copula function which joins together the copula functions from across the input feature space(by Eddie K H Ng, 2010)

STATISTICAL ANALYSIS

The word copula was first employed in a mathematical or statistical sense by in the theorem (which now bears his name) describing the functions that “join together” one-dimensional distribution functions to form multivariate distribution functions

One of the primary applications of copulas is in simulation and Monte Carlo studies Prokhorov, A and P Schmidt (2006), In this paper, we are used the problem of generating a sample from a specified joint distribution Such samples can then be used to study mathematical models of earthquakes systems, or for statistical seismicity, such as the comparison of a new statistical method with competitors with small sample results

Copulas model is applied on seismic temporal earthquake data catalog that can help to forecast medium and large earthquakes (Fig1,2) (Darsow, 1992)

The Iranian seismic temporal data catalog is provided by the International Institute of Earthquake Engineering and Seismology (IIEES)

This statistical procedure is presented showing a remarkable performance and the significance of the obtained results in seismicity analysis Copulas are also useful extensions and generalizations of approaches for modeling quantitative earthquake forecasting and its ability to predict the earthquake occurrence rate In this paper the results of modeling and statistical analysis are applied to evaluate the short and long term occurrence rates of future earthquakes regionally, to test these forecast in Alborz events in Iran (Figure 3) (Gorshkov, 2009,1991)

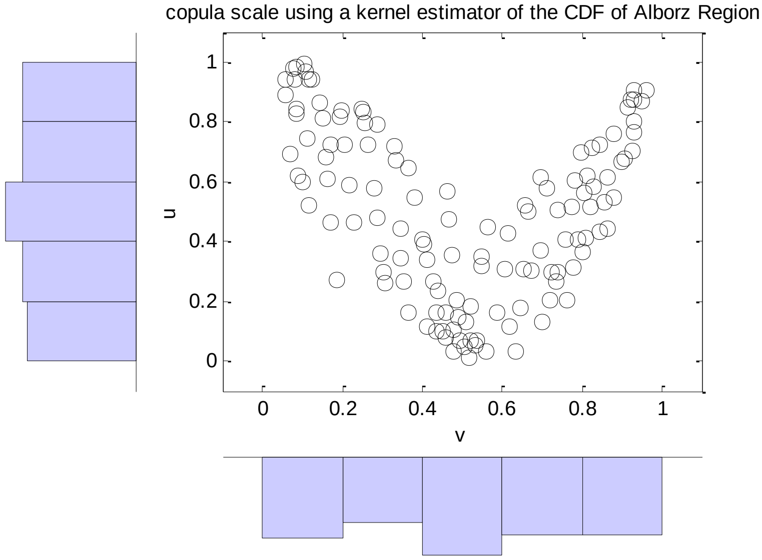

Figure3. Simulated data catalog using Copula scale (bya Kernel estimator) of Alborz region for Earthquake magnitude greater than 45 local magnitude

CONCLUSION

This paper introduces a new methodology to estimate the occurrence of significant earthquake events based on Copulas functions for forecasting earthquakes based on database of historic seismicity data In order to formulate the models, the input variables are selected among different seismicity area between significant seismic events in Alborz region in Iran

The resulting predictions reveal a strong correlation of the input variables with the interevent times, thus confirming the applicability of the proposed approach for successfully estimating large earthquake by recognition of Doughnut patterns before occured

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