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地震综合预报专家系统

Expert System for
Comprehensive Earthquake Prediction

ESCEP

地震出版社

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内 容 提 要

本书介绍了地震综合预报专家系统 ESCEP 的设计思想与总体构成和功能及其在实际地震预报中的应用与效果．全书分四个部分：第一部分是总论，第二部分是地震综合预报专家知识诸方面的内容精髓，第三部分是系统的软件实现，包括知识库、方法库、证据获取、推理、解释、图形图象与报表诸子系统的软件研制方法，第四部分是应用与展望，根据实际地震预报应用情况扼要介绍了 ESCEP 成功应用于全国年度地震预报的效果．

本书可作为地震科研人员和大学地球物理系的学生和研究生学习参考，也可供从事地质矿产、地球物理和人工智能—专家系统应用研究的科学工作者或爱好者参考．

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序 一

地震是一种严重的突发性自然灾害，大地震往往倾刻间就给人类造成灾难．本世纪以来，全世界因地震死亡的人数已达 260 万，占各类自然灾害死亡人数总和的 58%；仅 1976 年唐山地震，死亡即达 24 万人，造成的直接经济损失达 100 亿元．当代，国内外经济迅速发展，人口高度集中，地震灾害的潜在威胁将日趋严重．

几千年来，人类为了减轻地震灾害进行了不懈的努力．从预防为主的思想出发，1966 年邢台地震后，在党和政府的领导和周恩来总理的亲切关怀下，我国大力开展了地震预报研究，积累了丰富的经验．但是，由于地震过程是个极其复杂和困难的科学问题，当前国内外地震预报仍旧处于探索阶段．成功预报的例子仍然很少．地震预报迄今仍未取得突破性进展．

面对这样一个科学难题，需要尽可能观测和应用一切与之相关的事实和信息，需要吸取和应用当代各种学科与先进技术成果，并相互渗透，这将有益于地震学科和地震预报的发展．人工智能是当代新兴的前沿学科之一．局分析预报中心在国内外尚未广泛研究与开发的情况下，率先从经验性的前兆指标判据与震例综合分析出发，吸取预报专家知识的精华，应用人工智能高科技，研制出地震综合预报专家系统，推进了不同学科之间的渗透，且仔细进行震例检验，又努力应用于预报实际，经过两年多实际运行，取得了良好的成绩，明显地提高了预报效果．这对推进地震预报工作是具有重要意义的．

当前，国际上正在开展"国际减轻自然灾害十年"活动，减轻地震灾害是其中的重要一环．为了实现减灾的目的，我期望能有更多的类似成果出现，更希望地震综合预报专家系统研制组的同志们继续努力，今后做出更好的成绩，进一步推进与提高我国的地震预报水平．

方樟顺

1991.10

Preface I

Earthquake is a fearful and sudden natural disaster. A large earthquake may cause great catastrophe to human beings in a second. Since this Century, there have been about 2,600 thousand people killed by earthquakes in the world amounting to 58% of the death total caused by all kinds of naturel disasters. For instance, the Tangshan earthquake, 1976 in china killed 240,000 people, and caused the direct economical losses up to 10 billian chinese yuan. Nowadays with the economy developing rapidly both at home and abroad, population highly concentrated, the potential threats of earthquake hazards tend to be increased greatly.

In the past thousands of years, in order to reduce the seismic hazards, the human has made unremitting efforts. From the thinking of " putting prevention first ", after the Xingtai earthquake in 1966, under the leadership of Chinese Communist Party and government and the kind attention of Premier Zhou Enlai, the earthquake prediction researches have been carried out, energetically in China, and we have got rich experiences. However, because earthquake process is one of the extreme complex and difficult scientific problems, earthquake prediction is still in probing stage at home and abroad to date. There are a few successful prediction cases so far, and no breakthrough progress has been made in earthquake prediction practice.

Facing this difficult scientific puzzle, we must measure and use all facts and information associated with earthquakes, and absorb and apply all scientific results gained from various disciplines and advanced technology, so as to achieve interaction among various scientific domains for the better development of earthquake science and earthquake prediction research. Artificial Intelligence (AI) is one of the rising forward disciplines today. As there are no any extensive studings precedent and development of AI in earthquake aspect nationally and internationally, the Centre for Analysis and Prediction, SSB, has taken the lead in developing the Expert System for Comprehensive Earthquake Prediction(ESCEP) from the synthetical analysis on empirical precursory indices and criteria and earthquake cases, absorbing the essence of predicting expert's knowledge,and applying the high technology AI. And so the interaction and permeation among various disciplines have been promoted. They tested the ESCEP by using the earthquake cases carefully, and applied the ESCEP to predict the coming earthquakes actively. After practical operations of the ESCEP for more than 2 years, they have gained good achievements, and inhanced the predicting efficiency significantly. It is of primary importance to promote earthquake prediction research.

Currently the activity of " International Decade for Natural Disaster Reduction " is

under way, reducing the earthquake disaster is an important aspect in the Decade. In order to realize the goal of reducing disasters, I am expecting there will be more achievements like ESCEP in the future. It is my great hope that the scientists from the Research Group of ESCEP will continue to make efforts for obtaining better results , so as to further advance and raise the earthquake prediction level in China.

Fang Zhangshun
1991.10

序　二

作为当代新兴前沿学科之一的人工智能自1956年问世以来，已经取得了重大进展．在其应用研究中，近十多年来，专家系统已广泛应用于各种性质不同的领域，取得了不少实际成效．人工智能之所以迅速兴起，其主要原因在于它具有巨大的潜力．人工智能将使计算机能够解决那些至今人们还不知道如何解决的问题，不仅带来计算机软件和硬件的革命，而且正向各个领域渗透，促使这些领域的更新换代，从而促进和加快社会经济的发展．

地震预报至今是国内外一大科学难题．由于地震过程的复杂性，迄今地震预报仍未获得突破性进展．为了减轻地震灾害，国内外许多地震学家正在作出不懈的努力，大力发展地震观测系统，深入开展地震理论与预报方法的研究，同时，努力吸取国内外一切先进科学的最新成果，以便推进地震预报工作．

为了使分散的单个专家的能力汇集起来，构成专家集团并发挥其作用，为了以统一规范描述、存贮与管理、检验和应用分散专家的预报知识、判据与指标，克服以往地震综合预报或多或少存在的分散性不稳定性和主观性等缺陷，提高地震综合预报的系统性、稳定性与科学性，在国内外没有先例的情况下，1986至1989年，国家地震局分析预报中心研制了地震综合预报专家系统，简称为ESCEP．1989年10月通过国家地震局组织的专家鉴定．鉴定委员会由国内外知名的人工智能专家与地震预报专家组成，委员会认为该系统属国内首创，达到国际先进水平，实用有效，可以推广应用．我国一些新闻媒介报道了该系统研制成功的消息，日本、苏联、美国、伊朗等十几个多地震国家的地震专家都观看过该系统的运行表演，并给予了很好的评价．1990年初起，在不长时间内，该系统已推广到近20个省市自治区和地、市地震部门．1988年10月至今两年多来，国家地震局十几个局属单位均先后在地震预报中应用该系统，取得了较好的预报效果，在地震预报和减灾防灾中发挥了作用．

1989至1991年度，该系统已连续三年被用于全国年度地震趋势会商，作为主要手段之一，该系统推理得出的预报结果也被作为全国年度趋势预报结论的主要依据之一．1988年秋，研制组的同志应用该系统自动提取了一部分地震前兆异常，同时收集汇总了一部分其它前兆异常，进行推理和预报，得出了6个重点危险区，11月5日向领导汇报，接着在预报的第1号、第2号危险区连续发生了唐古拉山7.0级和澜沧7.6级与7.2级大地震；1988年底，局分析预报中心进一步汇集了当时全国的地震前兆，用该系统作预报推理和决策，从而在上述6个危险区的基础上又增加了2个危险区，共提出1989年度全国8个危险区，至1989年底，除台湾和西藏南部地区地震前兆台站缺少，资料不全，定为"盲区"，不参与统计外，其余地区5级以上地震、6级以上和7级以上地震基本上都发生于预报的危险区内或其邻近，对澜沧、唐古拉山地震，茫崖、小金、大同、溧阳等地震都作了较好预报，而且8个预报危险区上都发生了5级以上地震,其中5个区发生了6级以上地震．1989年底，采用与上述同样的方法，用该系统作了1990年度全国地震危险性三要素预报，至1990年底，该年度的大多数5级以上地震和6级以上地震（该年度全国无7级以上大震）都发生在预报的危险区上，对这期间发生的青海共和6.9级地震和天祝6.2级地震都作了较好的预报．乌恰西发生的6.4级地震位于新疆西部国界线（盲区）附

近，该地区台站少，资料不全，故而漏报．1990年底，又应用该系统作1991年度全国地震危险性三要素预报，提出了9个5级以上地震危险区，目前已有7个区发生了5级以上地震，绝大部分地震均发生于预报区上或其附近50km范围内．总起来看，地震综合预报专家系统具有较高的报准率，较小的虚报率，与当前国内外地震预报研究的实际水平相比，其预报效果良好．

地震综合预报专家系统吸取了地震综合预报领域专家知识的精华，以领域专家知识为基础，以电子计算机为工具，应用扩展的不精确推理方法进行推理，采用综合风险决策策略进行预报决策，实现了中强以上地震的中长期与短期计算机预报，是一个计算机智能化的综合预报系统．该系统的主要特点是：1.知识覆盖面比较宽，数据存储量大，知识内容比较新．吸收了地震综合预报攻关中的部分成果，在知识总结与应用中兼顾了经验预报、统计预报和某些孕震物理研究的成果；2.综和性强．基本上包括了地震综合预报中各个学科方法的判据指标及众多地震预报专家的知识和经验；3.实用性较好．基本上将地震综合预报的各个环节实现了计算机化、智能化．经过震例内符检验及实际预报应用，效果良好；4.易于扩充移植．该系统不论数据库、知识库及方法库都可以扩充，易于进一步完善提高和进行知识的补充更新．目前该系统既可在VAX／780、750等小型计算机上运行，还可在386微机、286（AT）机、IBM／PC—XT机及某些兼容机上运行，移植方便；5.操作简便，采用中、英文两种菜单提示；6.输出功能齐全、直观，用户界面友好．

地震综合预报是当前极其复杂而困难的科学问题．因此，尽管至今许多国家都在大力开展研究，而实际预报成功率仍然很低．但是地震灾害却严重地威胁着人类的生命与财产安全．当前国际上正在开展"减轻自然灾害十年"活动，这正表明人类减灾防灾的迫切愿望和决心．减轻地震灾害是减轻自然灾害计划中的关键一环，因而当前无论是国内或国际上对此都给予了很大关注．应用当代科学技术的新成果，努力提高地震预报的报准率，通过预防，减轻地震灾害的程度，最大限度地减轻地震造成的人员伤亡与财产损失，这是具有重大意义的．地震综合预报专家系统第一次将人工智能—专家系统这一新兴学科的成果与地震预报有机地结合于一体，成功地实现了不同学科之间的交叉渗透，所取得的进展和成果是令人鼓舞的，它不仅是我国地震综合预报智能化的一次成功尝试与实践，而且对地震综合预报，特别是中长期和中短期预报的规范化、自动化将起很大的促进作用．这项研究在计算机专家系统技术与地震预报研究的结合上达到了国际先进水平．希望该项目研制组的同志继续努力，进一步增强其功能，完善该系统，使其在地震预报中发挥更大的作用．

陈颙

1991.10

Preface II

Artificial Intelligency, as one of the contemporary frontier of science, has achieved great progress since its appearing in 1956. In the research of application, the expert system has been applied widely in all kinds of fields in the past ten years, with plenty of practical effects. The main reason with which the artificial intelligence arose so rapidly is that it has great potential ability. The artificial intelligence makes the computer be able to solve many problems which we don't know how to solve till now. It not only brings about the revolution of software and hardware, but also penetrates other fields and makes them revolution, then promotes and speeds up the development of social economy.

up to the date, earthquake prediction is a great scientific difficulty. Because of the complexity of the seismogenesis process,earthquake prediction still can not show its outstanding progress. In order to reduce the earthquake disaster, many seismologists at home and abroad are making efforts to develop seismic observation system, and study the theory of earthquake and the method of prediction deeply, meanwhile they also make effort to absorb the advanced scientific and technological achievement at home and abroad to improve the earthquake prediction.

In order to gather the ability of individual expert to form an expert group and make them effective, in order to identify the describing, accessing, managing, vertifying and applying the prediction knowledge and criteria of individual experts to overcome the shortcoming (such as dispersity, instability and subjectivity) which existed in the earthquake comprehensive prediction, in order to raise the systematization, stability and scientism of the earthquake comprehensive prediction, the Centre for Analysis and Prediction,State Seismological Bureau, has developed the expert system for comprehensive earthquake prediction (ESCEP) during 1986 to 1989, which is the first one in this field in the world. In Oct.1989, it passed the appraisal organized by State Seismological Bureau.The appraisal committee was consisted of the artificial intelligence experts and earthquake prediction experts who are the famous ones at home and abroad. They all maintained that this system is a pioneer one at home, advanced one abroad, and a very good practical and effective expert system, and can be extended to prediction practice. Some news medium of our country issued the information of this system success.Many seismic experts from more than ten countries, such as Japan, Soviet Union, United States of American, Iran and so on, watched the demonstration of this system, and had given good appraisals. Sine 1990, this system has been extended to about twenty provinces or regional seismological departments. From October in 1988 to now, more than ten bureaus under the State Seismological Bureau have used this system and obtained satisfactory prediction effects. It

really had made effect in the earthquake prediction as well as in the reducing and preventing disaster.

Since 1989, the ESCEP has been used to do the national coming earthquake prediction. As one of main means, the prediction results reasoned by ESCEP were regarded as one of main arguments of the national coming earthquakes. In the fall of 1988, the researchers used ESCEP to acquire one part of precusory anomalies automatically, meanwhile they gathered one part of other precursory anomalies to reason and make prediction, and obtained six predicting risk areas. Just in No. 1 risk area did $M=7.0$ Tanggulashan earthquake occur and in No. 2 risk area aoccurred $M=7.6$ and $M=7.2$ Lancan earthquakes. In the end of 1988, researchers gathered all national earthquake precursory anomalies. After their using ESCEP to reason, another two risk areas were added, in total eight risk areas were put forth in 1989. Till the end of 1989, except Taiwan and the southwest of Tibet from where we can't get the data of earthquake, almost all $M\geq5.0$ events,and all $M\geq6.0$ and all $M\geq7.0$ events occurred within or near the eight areas. What is more, within all eight predicting risk areas had occurred $M\geq5.0$ events,and in 5 risk areas occurred $M\geq6.0$ events. In the end of 1989, similar methods had been used in ESCEP to do the three indexes prediction of national earthquakes. Till the end of 1990, most of $M\geq5.0$ and $M\geq6.0$ events (no $M\geq7.0$ this year) occurred within the predicted areas. It made good prediction for $M=6.9$ in gonghe of Qinghai Province and Tianzhu $M=6.2$ events which occurred that year. In the end of 1990, ESCEP had been used to do the national earthquake prediction of next year, and nine $M\geq5.0$ risk areas were put forth. Till now seven of them had occurred $M\geq5.0$ events, most of them occurred within the risk areas or in the 50km from the risk areas. To sum up, ESCEP has high prediction ratio and low error prediction ratio, and is a very good effective expert system.

Expert system for comprehensive earthquake prediction is based on the recent new prediction knowledge of seismologists, with expanded imprecise reasoning method to do reasoning, and synthetic risk decision strategy to make medium-term and short-term prediction of strong earthquakes. It is a computer system, combining intelligence software. The main features are:

1. New contents and wide covered fields of knowledge, large data access. It gathered and included almost all of the expert's available experience, knowledge, criteria of experience prediction and statistic prediction, and some new achievements of seismogenesis researches.

2. Good comprehensibility. It included not only the criteria of each single discipline, but also the expert's knowledge and experience of multiple disciplines.

3. Good practicability. It computerized the comprehensive earthquake prediction and made them intelligence. The practical earthquake predictions showed good results.

4. Easily expanded and transplanted. The data-base, the knowledge-base and the method library of this system can be expanded and improved easily. Till now ESCEP can

be running not only on VAX/780 or 750, but also on 386, 286 (AT), IBM-PC/XT, as well as can be also easily transplanted on to some other compatible computers.

5.Conveniently to operate. It adopted menu management.

6.Good output function and user interface.

Earthquake prediction is a complex and difficult scientific problem. Although scientists in many countries make effort to solve it, the predicting ratio still maintains low. On the other hand, the earthquake disasters threaten mankind seriously. Now the activity of "International Decade for Natural Disaster Reduction" is carrying out in the world, which demonstrates the mankind's desire and determination of reducing and preventing disaster. Reducing earthquake disaster is the critical step of the plan of reducing natural disaster. So, now not only at home but also abroad are paying much more attention to it. It is significant that applying the new achievements of contemporary science and technology to rise the earthquake prediction ratio to maximumly reduce the number of died and injured and the loss of property. The ESCEP has combined the new achievements of artificial intelligence with earthquake prediction firstly, and has fulfilled successfully the penetration of different disciplines. It is not only a successful try in making the earthquake comprehensive prediction intelligence, but also plays a great role in the standardization and automation of earthquake comprehensive prediction, especially the long-term, medium-term and short-term earthquake prediction. The research has arrived the advanced level in the world in combining expert system with earthquake prediction. We hope the researchers make it more effective in the earthquake prediction.

Chen Rong
1991.10

编 者 的 话

本书是 ESCEP 理论、方法与应用的总结。全书以文集形式出版，但其全部内容在逻辑上是一个整体。全书分为四个部分，第一部分是总论，第二部分是综合预报知识、判据与指标，第三部分是 ESCEP 的软件实现，第四部分是系统的应用与展望。全书以方法论述为主旨，书的内容，尽量从实效出发。无论是总论或分述文章，均尽可能做到方法具体，以便有兴趣的读者读后能得到解决某些问题的方法要领。至于一般专家系统中知识表示、推理策略的论述，这方面专著颇多，此不赘述。

地震综合预报专家系统 ESCEP 是在国家地震局与局分析预报中心联合资助下研制成功的。在系统的研制过程中局领导和局分析预报中心有关领导和专家给予了大力的支持和帮助。方樟顺局长、陈章立、陈颛两位付局长对这项工作非常重视。从计划、总体设计和实施到验收，始终得到孙其政、李宣瑚、陈鑫连、罗兰格、冯德益、王秀文、徐京华的热忱支持和帮助。国防科技大学王朴、胡运发、高洪奎等在系统研制工作中给予了热情指导，国家地震局顾平、尹建军同志，清华大学林尧瑞教授审校了书中有关外文翻译，地震出版社商宏宽同志对本书的编写提供了热情的帮助。借此机会，作者一并致以诚挚谢意。

本书由朱岳清统一组稿编辑修改，由朱岳清、梅世蓉审定，由商宏宽终审终校。编辑组成员为朱岳清、梅世蓉、李彦巧、贾桂彩、陈颖、俞旭东、丁香，由李彦巧、贾桂彩、陈颖、丁香、俞旭东等录入排版。书中图件由孙彤、屈秀清、范荣芝等同志清绘。编辑组虽然作了很大努力，但由于水平与时间所限，书中可能还有错漏不当之处，请读者见谅并提出宝贵意见。

编 者

1991 年 10 月于北京.

Editor's Remarks

This book is the summarization of ESCEP. All the contents are connected each other logically. It is divided into 4 parts, the 1st part is the summary of ESCEP, the 2nd is about the predicting knowledge, the 3rd, on the software implementation, and the 4th part is the application and prospect.The major goal of the book is to describe the mothodology for developing ESCEP,the contents are in detailed as far as possible, so that the readers who are interested in this book will be able to get the essentials of the methods for solving certain problems from it.As there are many works available on the knowledge representation and inference methods of a general expert system, it is needn't to describe them in this book.

ESCEP is developed under joint support of State Seismological Bureau (SSB) and the Centre for Analysis and Prediction, SSB. Relevant leaders and scientists, from the State Seismological Bureau, the Centre for Analysis and Prediction, SSB, and other seismological units, have rendered great assistances in developping the ESCEP and editing and publishing this book.Mr.Fang Zhangshun, the SSB director, Mr.Chen Zhangli and Chen Rong, the SSB deputy directors,have attached primary importance to progress of this research project. Mr.Sun Qizheng, Li Xuanhu, Chen Xinlian, Luo Lange, feng Deyi, Wang Xiuwen, Xu Jinghua have dedicated their enthusiastic aids and guidance during the whole period from the proposal and specification establishment to the project implementation and acceptance. Prof.Wang Pu, Hu Yunfa, Gao Hongkui etc of Technological College of Changsha, have dedicated their assistance in developping ESCEP, Mr.Gu Ping, deputy director of Department of Intenational cooperation, SSB, and Mr.Yin Jianjun of SSB, Prof. Lin Yaorui of Qinghua University have checked and approved the English in this book. The authors are very much grateful to all of them for their help.

The works of the manuscript organization , edition and embellishing are undertaken by chief Editor Zhu Yueqing; the checking and approving work, by Zhu Yueqing and Mei Shirong. Finally Prof.Shang Hongkuan examined and verified all the drafts of whole book. Managing Editors are Zhu Yueqing, Mei Shirong, Li Yanqiao, Jia Guicai, Chen Ying, Yu Xudong, Ding Xiang.All the drafts are entered and edited and typesetted by Mrs. Li Yanqiao, Jia Guicai, Chen Ying, Ding Xiang and Mr. Yu Xudong. All figures in the book are drawn by Sun Tong, Qu Xiuqing, Fan Rongzhi. The editorial board has made great efforts, but there might be still some improper aspects in the book. Due to our limited scientific level and knowledge, therefore, any comments and corrections are greatly appreciated.

The Editorial Board
Oct .1991,Beijing.

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