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SEISMOLOGY

Software engineering's contribution to earthquake engineering

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ABSTRACT

Earthquakes are natural disasters regularly affecting Mexico. It is very important that all information about them is quickly obtained to speed up attention being provided for the affected population and, if possible, applying preventative action. Computer and specialised software are currently used for obtaining essential knowledge concerning seismic events. 22 software applications for seismic analysis have been examined in this study to define predominant characteristics, strengths and limitations, to determine the current status of this particular field and suggest lines for the advance for new developments or prototypes. This country's existing technological dependency is clearly shown (hardware and software). Academic cooperation between different branches of engineering should thus be encouraged for creating new domestic products.

Key words: seismic analysis software, seismic engineering, software engineering.

RESUMEN

México es un país generalmente afectado por terremotos. Es muy importante que toda la información acerca de este tipo de desastres naturales sea obtenida rápidamente para acelerar la atención y si es posible implementar acciones preventivas. A través de programas computacionales especializados se reúnen datos esenciales sobre eventos sísmicos. En total, en este estudio se examinaron 22 aplicaciones de software para análisis sísmicos que permiten definir las características predominantes, sus fortalezas y limitaciones, al tiempo que se determina el estado actual del campo y se sugieren líneas de avance para nuevos desarrollos o prototipos. Además, se expone la dependencia del país en materia tecnológica (software y hardware). La cooperación académica entre diferentes ramas de la ingeniería podría entonces motivar la creación de nuevos productos domésticos.

Palabras clave: Software de análisis sísimico, ingeniería sísimica, ingeniería de software

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Introduction

Earthquakes are natural disasters which have scourged mankind throughout history, leading to recurrent destruction, desolation and death. This kind of event is referred to several times in the bible, for example in Psalms 114:4; *"the mountains skipped like rams, the hills, like lambs,"* and in Apocalypse 11:13 can be read, *"And at that hour there was made a great earthquake, and the tenth part of the city fell: and there were slain in the earthquake names of men seven thousand: and the rest were cast into a fear, and gave glory to the God of heaven."* Entire cities have been razed and reduced to rubble because of the violent shaking of the ground.

Considerable damage has been caused and many have been made victims because of seaquakes, tsunamis, fires and conflagration resulting from an earthquake; these produce a severe impact on a country or region's economic activity and social life [4]. Scientific techniques and modern tools must be used in dealing with these problems.

2. Earthquakes in Mexico

Mexico is located on top of five tectonic layers whose relative movement produces some of the highest seismic and volcanic hazards in the world. Industrial cities are especially vulnerable (i.e. Tijuana, Tecate, Mexicali and some others in Baja California) because they share similar hazards with Los Angeles and San Francisco cities in the USA [2].

Figure 1 shows that the main hazard is represented by earthquakes occurring along Pacific coasts. This area is where earthquakes are frequently produced, in addition to those having most intensity, so they represent a serious danger for coastal locations but also affect the Valley of Mexico (even although Mexico City is 200 km away from here), due to the conditions of the soil on which the city was built.

Table 1 presents a historical extract of seismic data recorded, giving details about seismic events which have occurred in Mexico. This table concentrates information related to all earthquakes having a magnitude higher than 6 and where many have caused fatalities [6].

3. Studying earthquakes in Mexico

Using instruments for measuring earthquakes in Mexico began late in the nineteenth century when the Central Meteorological Observatory was set up. Later, on September 5th 1910, the National Seismological Service (NSS), an agency of National Geological Institute, was created and installed by presidential decree. Telegrapher operators provided data about earthquakes so that this could be published in monthly bulletins once a telegraphic network had been set up [8].

The NSS was created for providing early information for authorities, means of communication and the general public concerning earthquakes occurring in Mexico for determining the main parameters, such as magnitude and epicentre. Such data is published in monthly catalogues enabling researchers to evaluate the country's seismic hazards and the creation of an extensive database [7].

The Seismic Observation Network covers the set of seismic recording instruments (seismographs and accelerographs) available in a particular area for analysing local or regional seismicity. The NSS currently has a national network of modern seismographs; however, there are other local seismic networks operated by several institutions, such as the Valley of Mexico's Geophysics Institute's Network, the Autonomous University of Mexico's (UNAM) Engineering Institute's Telemetric Information System, the Seismic Network of the Colima University (RESCO) and the Centre for Scientific Research and Higher Education's (RESNOR) North-western Mexico Network, Baja California (CICESE), the Autonomous University of Puebla's (BUAP) Puebla city network, the Centre for Seismic Instrumentation and Registration (CIRES) and the National Centre for Disaster Prevention (CENAPRED) [9].

Damage to property and economic loss also increase in the event of an earthquake due to an increasing population, urbanisation and industrialisation being closer to areas of high seismic risk and the increasing cost of real estate. This is why the origin of earthquakes and their patterns should be studied to provide better understanding of their effects and, whenever possible, reduce consequent damage and economic loss.

Earthquakes are studied by seismic engineering to mitigate the damage they produce by designing, constructing and managing earthquake-resistant structures. This is essential for knowing where and why earthquakes originate and the type of soil where they occur because this influences the amplification or reduction of ground motion intensity when determining a region's seismic hazard.

4. Software for earthquake study

According to statistics, 11,515 earthquakes occurred in Mexico between 1st January 2009 and May 3rd 2012; 2,182 of them occurred in 2009, 3,402 in 2010, 4,162 in 2011 and 1,769 such events occurred in 2012. It seems that values have increased but in fact what has increased is the ability to detect them [11]. This has resulted from more equipment gradually and

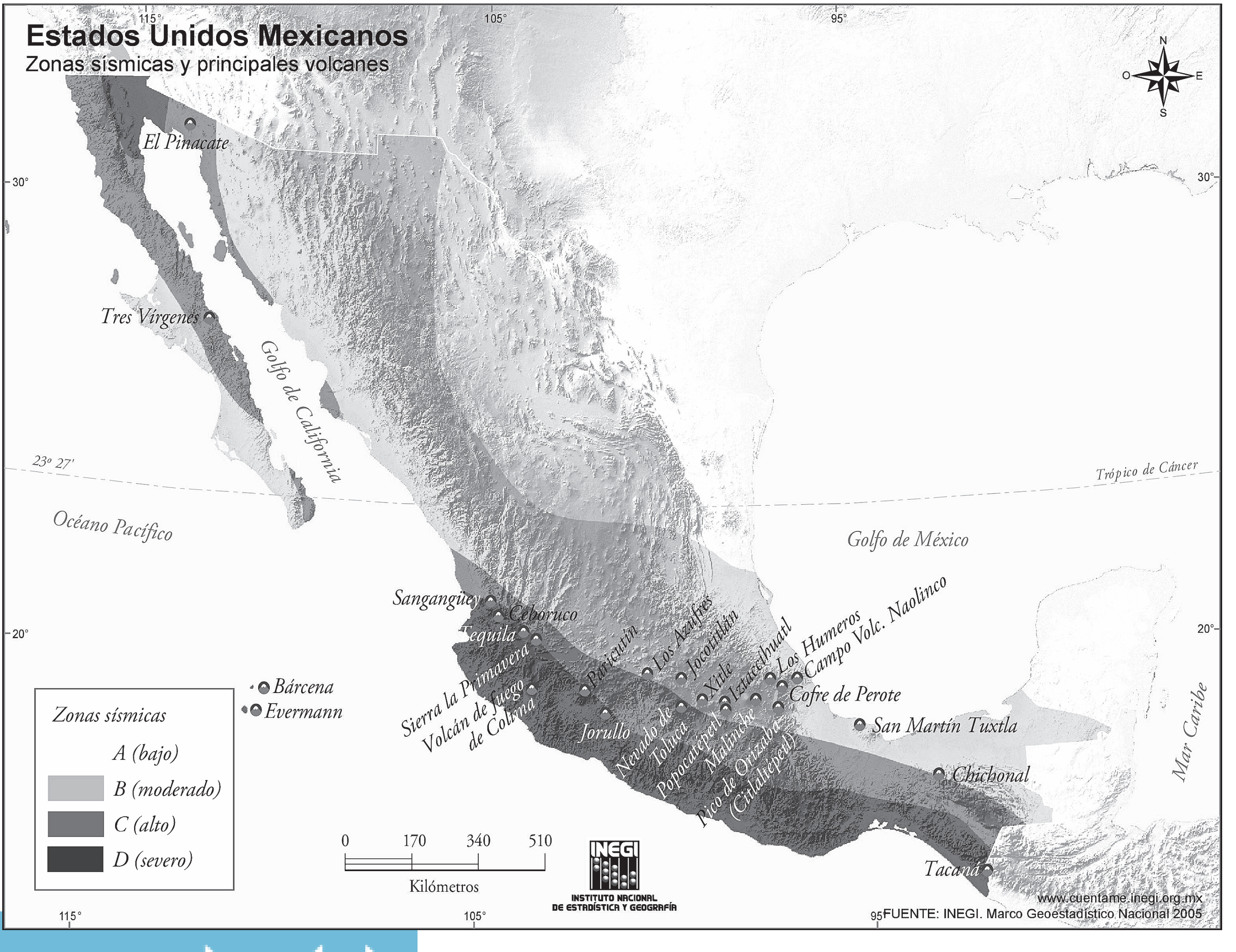

Figure1: Seismic regions and volcanic areas in Mexico [5]

constantly becoming integrated into seismic monitoring different networks. Such increase in information has enabled understanding different soil types, their behaviour during earthquakes and the effects occurring in them, as well as how they affect the society living on top of them.

Not surprisingly, as in many other areas of human performance, computer equipment has been used as support for processing large volumes of data thereby enabling seismic event to be processed quickly and effectively for producing useful information. So that specific software can be used for earthquake analysis, functions must be able to do repetitive tasks quickly and resolve common problems for people managing such data.

The main computer applications for seismic data processing were examined, i.e. BAP, Degtra, Earthworm, Fuente, Geogiga Microtremor, Hypo71, Icorrect, Insite, Loca 1.0, Pase, Pitsa, Preproc, Promax, Sac, Seisan, Seismosignal, Seispace, Seisplus, Seisware, Sigview, STK, Zmap (Figure 2). The following characteristics were considered when analysing them: release date, country of origin, platform architecture and operating system, programming language used for developing them and, last but not least, their cost.

4.1 By release date

Figure 2 shows that the development of this kind of software began in 1971, advancing steadily throughout the 1990s as a consequence of the growth of processing power together with a reduction in the cost in computer equipment. After 20 years, production slowed due to the increasing complexity of user requirements, because complete systems were being demanded which had to incorporate new components such as sophisticated graphical interfaces, compatibility between different file systems and the inclusion of data in several media with their corresponding interfaces.

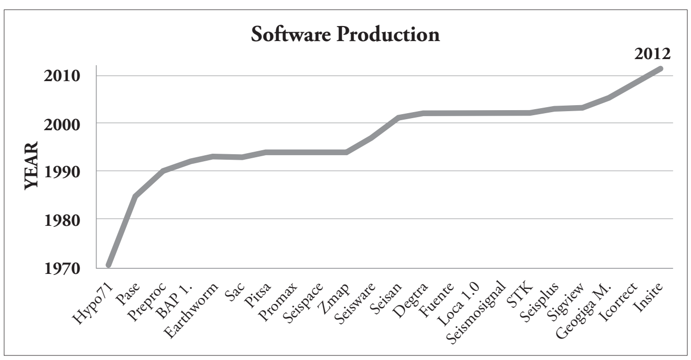

Figure 2: Years when applications for processing earthquake data were launched

4.2 By country of origin

Reviewing the countries producing the aforementioned software, they could be classified by continent or origin (i.e. America produced 14 and Europe 8), distributed as follows: Canada 3, USA 9 and Mexico and Peru one each. Germany produced 1, Spain 2 and France, Italy, Norway, the UK and Switzerland one each. A graphical representation of software production is presented in Figure 3.

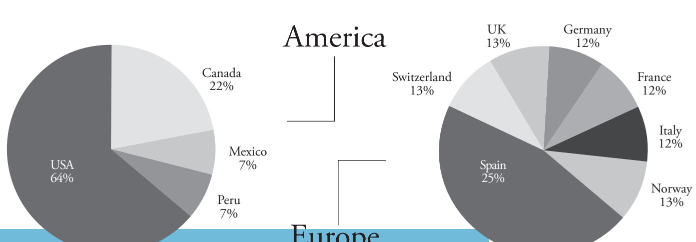

Figure 3: Countries in America and Europe producing seismic analysis software

4.3. By type of access

Some applications are free software, being extensively used in the academic institutions which created them; those which were created for commercial purposes obviously require a licence to be able to use such software legally.

Information was requested from the companies which created them in the case of licensed software; some provided technical data and product prices, whereas others only provided information if there were real interest in acquiring a product (i.e. data could not be obtained).

Information obtained about licensed software is given below; it includes country of origin, name of product and cost in 2011:

Canada	Geogiga Microtremor	$ 490 USD
USA	Sigview	$139 USD a single computer $1,290 USD a suite
Italy	Seismosignal	60 €
Switzerland	Zmap MatLab	2,000 €

4.3. By type of code

Special mention should be made about open source applications which provide access to source codes so that users know details about their operation and can modify them according to their requirements.

Earthworm and STK do not require any monetary contribution whereas other open source ones do such as Promax, Seispace and Seisplus.

Summarising, many European countries develop software for seismic analysis but the US is the leader in this area in America because it has largest number of software applications. Latin-America's low participation is also clear; only the Degtra application, developed by UNAM in 2002, is widely used in Mexico and some other countries [3].

4.3 By their platform

Table 2 presents the type of architecture that can be used by the software applications described above. It is clear that all the aforementioned applications considered personal computers because technological advances have increased their processing power, storage, portability and communications (obviously, encouraging more new users).

Table 2: Architecture for applications

Types of equipment	Total
VAX workstation	1
SGI workstation	2
SUN workstation	8
HP workstation	1
PC	22
MAC	2

When considering an operating system it can be observed that as most applications use personal computers, then PCs predominate regarding different types of operating system (Table 3). The RedHat version for Linux is included. Different versions of Windows have been included (i.e. Win32, 98, 2000, Millennium, XP, Vista and version 7).

Table 3: Operating system

Name	Total
DOS	5
HP-UX	2
Irix	2
Linux	7
OSX	2
Solaris	7
SunOS	1
Unix	2
VMS	1
Windows	15

4.4. By implementation language

Another evaluation parameter considered was that related to programming language used for creating analysis applications. Applications created around the 1970s were developed in several versions of FORTRAN, like 77, 90 and later even VFortran. Regarding C language, it was found that some applications were complemented with functions or libraries created in some other language or tool, like FORTRAN (for reusing previous codes) and Oracle. However, the kind of application where it was almost impossible to get information about programming language used in development is considered in the last category.

Table 4 contains the most commonly used programming languages for developing seismic analysis software; half of them were created with free access software like C language. Four products involved using licensed software but some did not specify the programming language they used in development. High complexity interfaces and sophisticated functions were observed for these applications, meaning that they were probably created with licensed software.

Table 4: Programming language

Name	Total
C	2
C with other	3
Fortran	6
GTK	1
MatLab	3
Not specified	7

This study thus found that interest in seismic engineering has motivated all people involved in earthquake studies (such as geophysicists, geologists, engineers) regarding intensive and extensive use of computer equipment and software tools. This has promoted their participation in implementing their own algorithms in convenient and available programming languages, such as FORTRAN and the emerging C language.

However, not only computer architectures have evolved but also user requirements. Simple interfaces became replaced by those having high definition and graphical displays, new components being included such as mouse, camera and speakers to offer multimedia information. This is why this type of application almost stopped being produced as it is not so easy to produce a programme as it was 40 years ago.

Several things have evolved such as equipment, requirements, programming languages and also how to use them, as have the people who create engineering software. This implies that we must encourage and support national scientific development resulting in new technologies for producing effective solutions to a country's problems. Academic institutions can take a first step towards low-cost application development for resolving different problems in all engineering areas.

Conclusions

Earthquake engineering and related sciences' contribution towards understanding and evaluating earthquakes means that their effects must become minimised and the losses affecting society reduced. It should also be considered that the effects of natural disasters depend on economic, social and political factors [1].

It is the duty of science to transform the natural misfortune involved in an earthquake occurring into an opportunity for innovation and technological development in diverse areas such as earthquake engineering and of course, software engineering. Producing earthquake analysis software is definitely an essential tool for achieving such goals more efficiently, quickly and accurately.

Software developers' participation in other disciplines must thus be expanded to contribute towards the understanding and management of national seismic hazards and ensure technological independence.

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