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The John A. Blume Earthquake Engineering Center

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GREGORY DEIERLEIN NAMED DEPUTY DIRECTOR

Professor Gregory Deierlein, Associate Director of the Blume Center, was appointed Deputy Director for Research of the Pacific Earthquake Engineering Research (PEER) Center. The Deputy Director's position is to lead the management team of the PEER Research program, which has an annual budget of over $4 million and involves researchers at PEER's nine core universities and affiliate institutions.

HARESH SHAH HONORED

The Honors Committee of the International Insurance Society has selected Professor Emeritus Haresh C. Shah for the John S. Bickley Gold Medal for Excellence Award. The award is given to a person who has made a singularly creative or innovative contribution to insurance thought, practice, or education that has been adopted by the industry or society. The award was given to Professor Shah on July 10, 2000 during the formal awards dinner in Vancouver, British Columbia.

Professor Shah is well known for his work in developing financial and insurance risk management strategies for catastrophic events such as earthquakes and hurricanes. He is author or co-author of more than 250 reports and papers. Professor Shah is the founder and former co-director of the John A. Blume Earthquake Engineering Center and the former chairman of the Civil and Environmental Engineering Department.

THE FIRST SHAH FAMILY LECTURE

Professor Richard J. Zeckhauser, Professor of Political Economy at Harvard University, presented the first Shah Family Lecture: "Risk, Costs, and Insurance: Lessons from Health Care" on April 7, 2000 for CEE. An informal discussion session was held in the Blume Center Library prior to the lecture.

ALUMNI NEWS

Stephanie King (MS '90, PhD '94) and **Christopher Rojahn** (MS '67) welcomed their third child, and second son, *Spencer Chase King Rojahn,* on July 13. Spencer weighed 8 lb, 15.2 oz and was 21.5 inches long at birth. Our heartiest congratulations!

BLUME CENTER NEWS

Prof. Kincho Law presented a paper on *"Internet-based CAD and Distributed Application Services"* at the Hong Kong University of Science and Technology on March 13.

A paper on *"Seismic Damage Indices and Near-Collapse Performance Assessment in Composite Moment Frames,"* **Mehanny, S.F.** and **Deierlein, G.G**.; was presented by **Prof. Gregory Deierlein** at the 6th ASCCS International Conference on Steel and Concrete Composite Structures in Los Angeles on March 20-21.

Prof. Gregory Deierlein presented *"On Assessing Near Collapse in Seismic Performance-Based Design"*, **Deierlein, G.G.** and **Mehanny, S.F.**; at the ASCE Structure's Congress in Philadelphia on May 7-10.

In May, Ph.D. Candidate, **Jun Peng**, (Prof. Law, advisor) presented a paper on *"Framework for Collaborative Structural Analysis Software Development,"* at the Structures Congress 2000.

PEER held its Annual Meeting and PEER/NSF Site Review on May 23-25. **Profs. Gregory Deierlein**, **C. Allin Cornell** and **Anne Kiremidjian** made presentations, with **Profs. Kincho Law**, **Laura Lowes**, **Charles Menun** and **Eduardo Miranda** also attending and participating in the workshops and meetings. Several students presented posters at the PEER Student Poster Session: **Ayse Hortacsu, Mark Audigier** and **Dimitris Pachakis** (Kiremidjian), **Jun Peng** (Law), **Rohit Kaul** (Deierlein), **Arash Altoontash** (Lowes), **Ricardo Medina, Luis Ibarra,** and **Ashraf Ayoub** (Krawinkler), and **Fatemeh Jalayer** (Cornell).

Prof. Greg Deierlein presented a paper on *"Seismic Design of Composite Moment-Framed Buildings Case Studies and Code Implications,"* **Mehanny, S.S.**, **Cordova, P.** and **Deierlein, G.G.**; at the Engineering Foundation Conference - Composite Construction IV, held in Banff, Canada on May 28-June 2.

Prof. Anne Kiremidjian participated in a special workshop on June 5 and 6 sponsored by USGS in Boulder, CO on *"How can USGS improve information for loss estimation?"*

On June 6 at the A/E/C Systems 2000 in Washington D.C., **Prof. Kincho Law** presented a paper on *"Automated Processing of Design Standards"*.

Prof. Anne Kiremidjian presented *"A Port Operations Simulation Model for Seismic Risk Assessment,"* **Kiremidjian, A.**, **Audigier, M.**, and **Pachakis, D.**; at the Simulation Symposium in Monte Carlo, June 17-21.

Markov DFT Models of Non-Stationary Ground Motion

By Hjörtur Thráinsson, Anne S. Kiremidjian and Steven R.Winterstein

Introduction

In recent years, the utilization of earthquake ground motion time histories has grown considerably in the field of earthquake engineering. Time histories of earthquake ground motion are, for example, used in the design and analysis of civil structures, and to correlate damage to ground motion characteristics. It is very unlikely, however, that ground motion recordings will be available for all sites and conditions of interest. Hence, there is a need for efficient methods to simulate earthquake ground motion.

In this article, a new model is presented to simulate non-stationary earthquake ground motion. A Markovian phase angle model is applied to the discrete Fourier transform (DFT) to describe the non-stationarity. A Markov DFT (MDFT) model is developed from the well-established theory of narrow-band stationary Gaussian processes, interchanging the roles of frequency and time. The development of this model is described in Blume Center Report No. 134, along with a comprehensive quantitative model validation.

Theoretical Background

The Fourier phase angles of digital earthquake accelerograms are commonly assumed to be mutually independent, as well as independent of all Fourier amplitudes. In addition, the phase angles are typically assumed to be uniformly distributed over [-p, p]. For a stationary Gaussian process, it can be shown that these are valid assumptions. However, as shown in Figure 1, this is not the case for a typical non-stationary ground motion record. Even though the phase angles themselves appear to be uniformly distributed, the phase differences are not. The mean phase difference is independent of the amplitude, but the dispersion around the mean decreases with the amplitude.

Building on the theory of narrow-band stationary Gaussian processes, and interchanging the roles of frequency and time, the phase differences are modeled by a normal distribution, where the mean phase difference is constant, but the standard deviation is inversely proportional to the Fourier amplitude. The phase difference distribution is completely defined by two parameters, μ and δ, which are related to the energy centroid and the duration of the accelerogram in the time domain, respectively. Given μ and δ, the DFT is simulated by (i) generating standard Rayleigh amplitudes, and (ii) generating the phase angle at frequency k+1 by adding the simulated phase difference, which is drawn from a normal distribution conditional on the amplitude of the previous frequency component, to the known phase angle at the k-th frequency. Finally, this simulated DFT can be scaled to match a target (synthetic or recorded) Fourier amplitude spectrum.

Simulated Time Histories

Figures 2 and 3 show sample simulations based on a record obtained in the 1989 Loma Prieta earthquake. Figure 2 shows the recorded and one simulated time history. The simulated ground motion is obtained by inverting the simulated DFT, where the parameters μ and δ are estimated from the recorded time history. In Figure 3, the linear elastic acceleration response spectra are displayed. The dashed lines represent the response spectra of ten simulations, while the solid, thick line is the response spectrum of the recorded accelerogram.

Figure 4 shows summary statistics of spectral acceleration from ground motion simulations for the 1994 Northridge earthquake at 45 ground motion recording stations operated under the California Strong Motion Instrumentation Program (CSMIP) by the California Division of Mines and Geology. The mean and the mean plus and minus one standard deviation from ten simulations are plotted versus the recorded ground motion level. The spectral accelerations correspond to natural periods of 0, 0.3, 1.0 and 2.0 seconds. The non-zero periods are chosen because they are often taken as representative of the fundamental period for low-rise, mid-rise, and high-rise steel frame structures. From Figure 4 it can be concluded that the simulated ground motion is statistically consistent with the recorded time histories across the various stations. (For example, 68% of all outcomes will lie within one standard deviation of the mean for a Gaussian distribution.) The recorded quantity is never more than two standard deviations away from the corresponding mean from ten simulations.

Discussion and Conclusions

Ground motion time histories that are simulated using this two-parameter MDFT model are found to capture well pertinent characteristics of recorded time histories. The MDFT model does not depend on a particular Fourier amplitude model; the user can employ any amplitude model – even a target power spectral density or a target response spectrum. In addition, the MDFT model can be used to generate a number of "equivalent" ground motion time histories from a target accelerogram.

A database of uniformly processed California records has been used to develop prediction formulas for the model parameters. The input for the prediction formulas is the moment magnitude of the earthquake, the source-to-site distance, and the NEHRP site classification. These relations can be used for regional seismic hazard and risk analyses, as well as for the design and analysis of individual civil structures.

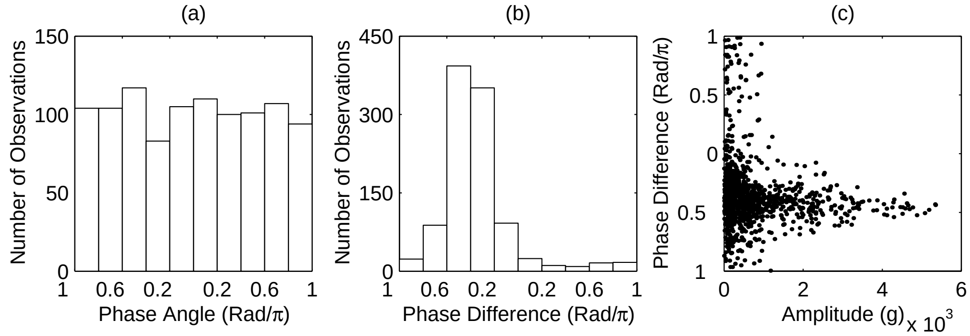

Figure 1. Observed phase angles and phase differences for the east-west component of the Santa Cruz record from the 1989 Loma Prieta, California earthquake. (a) Histogram of phase angles; (b) histogram of phase differences; (c) phase differences vs. amplitude.

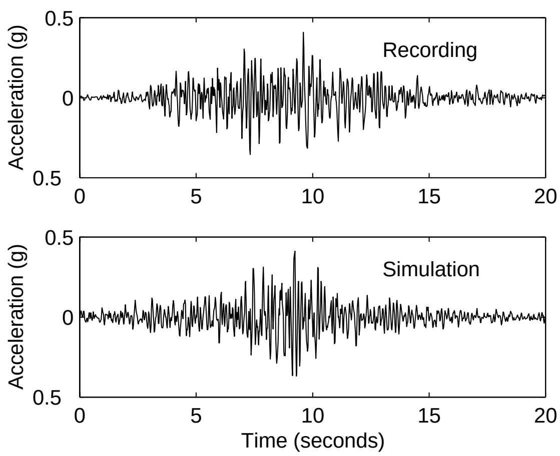

Figure 2. Recorded and simulated accelerograms; the same Santa Cruz record as in Figure 1.

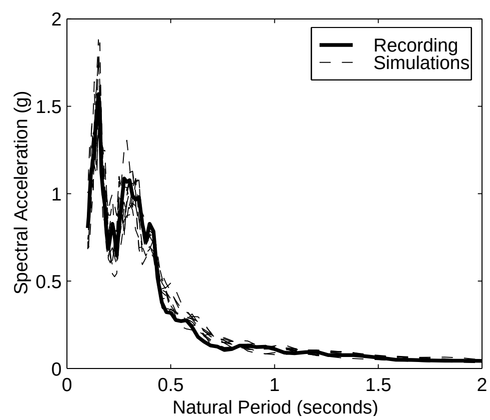

Figure 3. Pseudo acceleration response spectra (5% damping); same Santa Cruz record.

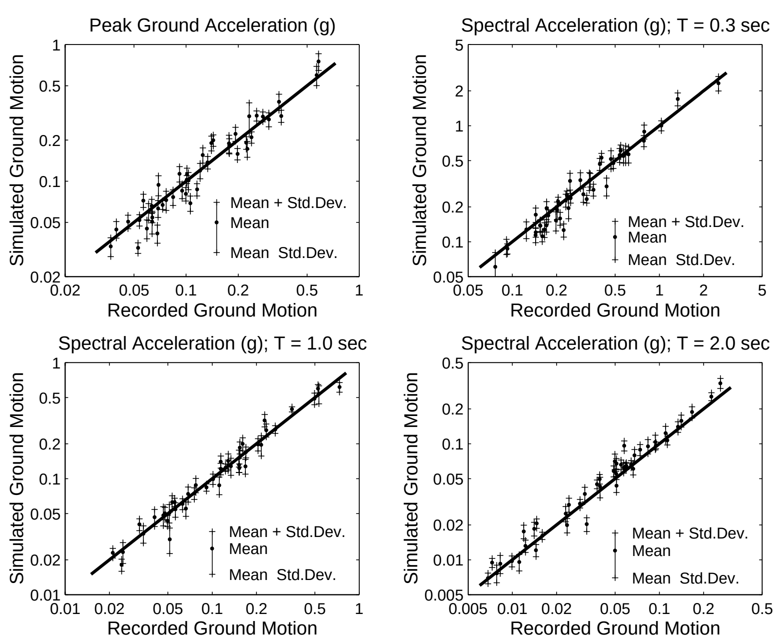

Figure 4. Spectral acceleration statistics from ten simulations vs. recorded spectral accelerations at 45 CSMIP stations during the 1994 Northridge, California earthquake.

AWARDS

Gregory Deierleien, 2000 Walter L. Huber Civil Engineering Research Prize (ASCE) for "practice oriented research on composite steel and concrete building structures and for contributions in developing design guidelines for this type of construction."

Gregory Deierlein, 2000 State-of-the-Art Award for paper co-authored with the ASCE Task Committee on Design Criteria for Composite Structures in Steel and Concrete, "Design Guide for Partially Restrained Composite Connections," Jl. of Struct. Engr., ASCE, Oct. 1998.

SPRING 2000 GRADUATES

Congratulations to the Structural Engineering and Geomechanics students who graduated in June. **Scott Breneman** and **Charles S. Han** received their PhD. degrees, Scott is currently working at Realtime Innovations and Charles will be working at Autodesk, Inc.

Our program also had 25 MS graduates: **Mark Audigier** (US Air Force), **Alice Chen**, **Mary Dickson** (US Navy), **Cortney Fried**, **Erich Gordon**, **Chad Green**, **Rie Lee Ishida**, **Christian Heimple** (Thornton-Tomasetti Assoc.), **Michael Hughes**, **Lori Huneryager**, **Michael Jewsbury** (Skilling Ward Magnussen Barkshire, Inc.), **Amit Kanvinde**, **Eric Lachance** (USMA, West Point), **Ting Ting Lau**, **Thomas Lau**, **Rebecca Lee**, **Ascencion Elizalde Molina**, **Victor Nakano** (USMA, West Point), **Stratton Newbert** (Weidlinger & Assoc., NY), **Yuki Ohashi** (Livermore/Sandia National Lab), **Yoshihiro Sasaki** (Kajima Corporation), **Reid VanderSchaaf** (USMA, West Point), **Gabriela Vergara-Reyes**, **Jonathon Wong**, and **Gee Liek Yeo.**

RESEARCH FUNDING

"Building-specific loss estimation methodology," **Eduardo Miranda** and **Anne S. Kiremidjian**, awarded by PEER-NSF.

"Risk Analysis of Designated Highway System," **Anne S. Kiremidjian**, **Samuel Chiu** and **James Moore**, years 3 and 4 funding awarded by PEER.

"Process Specification and Simulation," **Kincho Law**, awarded by NIST, 6/2000-6/2001.

"A Distributed Software Platform for Nonlinear Dynamic Analysis," **Kincho Law**, awarded by PEER, 5/2000-4/2001.

"REGBASE: A Distributed Information Infrastructure for Regulation Management and Compliance Checking," **Kincho Law**, NSF, 7/2000-6/2003.

ADMINISTRATIVE CHANGES

Kymberly Eliot, Program Coordinator, left the Structural Engineering and Geomechanics program in March to work as Exec. Asst. for Hemant Shah at RMS (Risk Management Solutions). We wish her the best.

Taking Kym's place as Program Coordinator is **Liz Marsh**. Liz worked at Stanford Hospital in Surgical Pathology as a Lab Technician before joining the Structures Program in March. She can be reached at (650) 723-4121 in Terman Bldg. Room #232.

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