A Computer-Aided Visualization Tool for Stochastic Theory Education in Water Resources Engineering

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ABSTRACT: In this paper, we propose and demonstrate the proof-of-concept for a computer-aided visualization tool for stochastic theory education in water resources engineering. Using Java Native Interfacing, the tool can wrap a space-time stochastic model written in any computer language and also not require any specific language compiler during tool usage. This feature also allows the tool to be implemented very easily on any configuration of currently used classroom PCs. We also gauged the merit of a computer-aided visualization tool in the classroom by conducting a survey of the civil engineering (CE) curricula of US universities. Questionnaires were distributed to the instructors via an online survey. Eighty-four percent of the universities surveyed were found to offer a general semblance of stochastic theory education in their curriculum for CE. A similar percentage of the total 241 courses that we initially surveyed were found to be available at the graduate level, while 4.5% and 11.5% were either dual-listed or undergraduate-level courses, respectively. Forty universities were found to have complete (integrated) courses dedicated to stochastic theory education (or a near-relative related discipline). 11.2% (27) of these courses were relevant to water resources engineering, while only 9.5% (23 courses) were related to surface water hydrology. Only 62.5% of instructors were active users of some kind of computer-aided visualization tools for classroom instruction. All instructors believed that a rapid visualization system to represent the effect of input (i.e., an aspect of stochastic theory) on output (i.e., application or representation of variability) would enhance the technology as a learning tool. Surveyed instructors were unanimous in their willingness to integrate such an instruction tool for teaching theory using real-world examples of water resources engineering. However, 42% felt that such a tool would need to be user-friendly and graphically very attractive in

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order to be popular among students. We believe that with the demonstration of proof-of-concept of our proposed computer-aided visualization tool, the effectiveness of modernizing course curricula in CE for undergraduate water resources education can be made more compatible with the needs of the 21st century and that there is indeed sustainable demand in the classrooms for its institutional development. Comput Appl Eng Educ 14: 1–14, 2009; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20233

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INTRODUCTION

Stochastic theory is a very important subject matter in any engineering discipline. It helps describe the omni-present uncertainty in man-made or natural systems and further helps us to mathematically model it for prediction. Most engineering curricula have some element of stochastic theory delivered as learning objectives. However, research accumulated over the last two decades indicate that the existing teaching paradigm of stochastic theory that is conventionally adopted in classrooms may be inadequate and in need of modification. Calls for a change in teaching probability theory in the classroom have been gaining widespread recognition [1]. This change ranges from demonstrating a collection of unrelated methods illustrated by coin tossing or dice-rolling to translating to real-world problems (e.g., [2,3]).

In the modeling of natural water resources systems in civil engineering (CE), stochastic theory receives particularly greater importance due to heightened awareness of the limitations of deterministic approaches to modeling [4], scale incongruity between input data such as rainfall and hydrologic model grids [5], and the unpredictable heterogeneity of naturally occurring variables of the land form (e.g., vegetation, topography, soils, geology, etc.). Thus, it has become increasingly imperative nowadays to use stochastic/statistical concepts to advance the hydrologic science domain of water resources engineering by bridging the gap between current observation capability and the model's predictive uncertainty [6].

The emerging research contours on water resources discipline also indicate a fast evolution towards greater use of stochastic methods. This recognition therefore warrants prior knowledge of computational skills for the novice graduate research student. This consequently raises a major demand on the admission criterion for a graduate research program that entering students must be well prepared a priori on the computational aspects of stochastic theory for conducting independent research in the water resources area. Huddleston et al. [7] however warns that as an applied science, there exists a natural tension between the study of fundamental scientific theory and instruction in the application of analysis and design methodologies within undergraduate engineering curricula. Most engineering courses are structured to emphasize the pertinent physical, chemical, and biological processes that are then augmented by studying specific problem solving skills applied to systems of engineering interest. Consequently, the level of application complexity and realism introduced to undergraduates is often limited by students' computational capability. Instructors must diligently balance the need to emphasize the engineering system physics versus instruction in numerical methods used to solve resulting mathematical equations. Student comprehension of basic concepts on stochastic theory may therefore be often impeded by their ability to master archaic computational skills [8,9].

Hence, in the current state-of-the-art, it becomes unrealistic to expect that entering graduate students will be adequately prepared to embark on advanced level research on water resources engineering involving stochastic theory. The realization of the practical importance of stochastic concepts in modeling natural phenomenon in water resources should therefore start early for the students in the undergraduate classroom [9]. Unfortunately, most engineering university baccalaureate programs seem to introduce students to these concepts fully only at the graduate level. This often makes it challenging for the fresh graduate student to grasp the value and successfully implement it in his/her research experiments in parallel. In particular, the diverse but foundational concepts making up stochastic theory, such as random variables and processes, probability density functions, moments, geostatistics, autocorrelation, random field generation, time-series analysis, etc., can overburden freshmen graduate students unless particular care is taken in demonstrating these concepts via real-world examples employing computer-assisted tools. Yet, the conventional teaching paradigm for delivering stochastic theory to model the variability of such natural systems continues to rest mostly on text-based pedagogy based on deductive reasoning and involving comprehensive stochastic theory books (such as [6,10]). It is our collective opinion that, these complex mathematical concepts on stochastic theory as presented in a text book, while comprising a fundamentally necessary component for instruction, should be made more effective and inductive through the application of an additional instructional medium [11].

A computer-aided graphics-based (visualization) learning system can potentially enhance the capacity of students to conduct independent research more effectively by training them in computational applications of stochastic theory. Very recently, Stern et al. [12] has demonstrated the importance of integrating computer-assisted learning and simulation technology in undergraduate engineering courses relevant to computational fluid dynamics. Thus, if students are given early exposure to this mode of instruction at the undergraduate-level and allowed to immerse in an intensive research experience, better prepared students could be cultivated for a state-of-the-art graduate research program on water resources involving stochastic theory across institutions nationwide.

For such a system to be effective, we believe the computer-aided visualization scheme should have the following features: (1) real-world application of a wide range of concepts of stochastic theory via a practical tool that allows convenient computational modeling of the variability of natural phenomena; (2) full interactive control to students over the tool to allow them to conveniently and rapidly modify concepts, parameter values through add/remove options, observe corresponding effect and thereby foster active learning and generate research curiosity; (3) multimedia and a computer assisted technology, such as a Graphical User Interface (GUI), that combines (1) and (2) and further enhances the user-friendliness of the modular modeling system. Such a system, by allowing the students to independently interpret fundamental concepts using an additional graphical medium, can enhance the potential to stimulate research interest in students by probing them to seek answers to science questions independently [11].

To the best of our knowledge, there is currently no GUI-based tool for stochastic theory education in water resources engineering. Our review of existing softwares in the STEM area revealed that the relevant GUI educational tools are mostly web-based. For example, Lai and Wang [13] developed a web-based interactive plane geometry system for mathematical education called GeoSVG. Wang et al. [14] prototyped a web-based mathematics education (WME) system based on an Internet programming language that searches for mathematical concepts on the Internet. Another example is the Utah Virtual Lab [15] where students can learn about science and statistics using a JAVA program. Some other recent examples on water resources educational tools (but not involving stochastic theory) are Rivvas et al. [16] on hydraulic engineering instruction, Valocchi and Werth [17] and Li and Liu [18] on groundwater pollution education and Kaarahan and Ayvaz [19] on the use of spreadsheets.

Hence, we believe that the development of GUI tools (i.e., computer aided visualization techniques) for stochastic theory education in water resources engineering is timely. Recent research indicates that multimedia can be effective in enhancing learning when the "learning," "subject" and the "student" are clearly defined [20]. We are also motivated by an analogous demonstration by [21] where student understanding of quantum mechanics, often a difficult topic to learn, has been found to improve dramatically via coupling computer-based visualization tools with research-based pedagogical strategies developed by the *Kansas Physics Education Group* (see http://perg.phys.ksu.edu/vqm/).

However, to assess the validity of our assumption that stochastic theory education in water resources engineering can be improved through a GUI-based computer instruction and to further identify if current curricula has an inherent demand for such approaches, there is a need to first survey the curriculum that is adopted by the universities nationwide. Findings from a survey can be expected to answer the following type of questions: *Is there a need for modernizing curriculum in stochastic theory for water resources engineering for the 21st century? Should this modernization be planned at the graduate or the undergraduate level? And, how much is the demand for use of such computer assisted schemes by the instructors?*

In the remaining part of the paper we present findings from our survey. Second section outlines the methodology used for the survey while third section discusses the results of the survey. In fourth section, we present the proof-of-concept of a GUI tool constructed with Java Native Interfacing (JNI). Finally, in fifth section, we present the conclusions of our study.

METHODOLOGY

We conducted a two tiered survey. In the first tier, our aim was to perform a broad-based survey and collect baseline data on the universal set of courses in CE that teach any element of stochastic theory or its nearest relative sub-area (numerical methods, quantitative methods) as learning objectives. Using public domain information available on the World Wide Web, we downloaded information from university websites on CE curricula on the following key parameters:

(i) Name of University
(ii) Course Name in CE
(iii) Course details—Number of Credit Hours, Website address (course website), Instructor Name, Instructor Email
(iv) Official catalog description of syllabus.

The list of universities surveyed is provided in Appendix 1. The search for courses in the tier 1 survey was governed by a blanket keyword match in course titles or course catalog descriptions for the following words: ‘‘Stochastic,’’ ‘‘Numerical,’’ ‘‘Statistics,’’ ‘‘Quantitative,’’ and ‘‘Probabilistic.’’ The courses identified in this manner are therefore subject to the following assumptions:

(1) Information posted by university course catalog or instructor's website on the World Wide Web is accurate and up to date.
(2) All relevant course content information is available from the World Wide Web.
(3) All courses are actively offered on a routine basis by instructors.
(4) The course has a significant amount of stochastic theory component (or a nearest relative discipline) delivered as course content.

In our 2nd tier survey, we first narrowed down our search to those courses that offered a complete and dedicated instruction of stochastic theory in water resources engineering (including: surface water, ground water, and hydrometeorology). This screening was done on the basis of examination of the course title and course description. For example, a course title such as ‘‘Stochastic Hydrology’’ was considered a proper course on stochastic theory for water resources engineering. On the other hand, a course titled ‘‘Water Resources Systems Analysis,’’ despite lacking the word ‘‘stochastic’’ or ‘‘probabilistic’’ in its title, was considered acceptable because of the traditional dominance of stochastic concepts delivered as part of the course syllabus. Once the courses specific to stochastic theory in water resources were identified, instructors were sent a short questionnaire via email to assess the inherent demand of computer-assisted tools. Appendix 2 provides a summary of the questionnaire that was used for the email survey. A total of 19 questions were asked. These questions probed the current instruction style and the gauged the instructor's opinion on the potential utility of a computer assisted GUI-based instruction scheme. For maximizing the probability of response, we used an online web service offered by www.surveymonkey.com that is tailored for conducting such questionnaire surveys via the Internet in an efficient manner (see www.suveymonkey.com). *Surveymonkey*™ allows the creation of questionnaires online where responses can be directly saved using the Internet. This therefore avoids the need for mailing back the questionnaire by the respondents which can usually be an impediment to maximizing the response rate.

SURVEY RESULTS

Tier One Survey

Out of the 67 universities surveyed, we failed to identify any relevant stochastic theory-related course in CE for 10 universities. This can be attributed to the inherent limitations of any web-based survey because it is highly unlikely that an accredited CE curriculum would not address the basic elements of statistics and probability. Nevertheless, the 84% of the universities that were found via the web to offer stochastic theory education of some sort testified the general recognition of importance curriculum developers place on this subject matter as part of the overall CE discipline. The total number of courses that were identified in this broad-based fashion was 241. A similar percentage (84%) of theses courses were found to be available only at the graduate level, while 4.5% and 11.5% were either dual-listed or undergraduate-level courses, respectively. The current overwhelming representation of graduate courses perhaps underscores a current need to rethink strategies and strive for a more equitable distribution that would facilitate a smoother learning experience. For example, creating more undergraduate variants of these graduate courses and offering them early in a student's CE education experience are likely to further strengthen the appreciation of the concepts on stochastic methods by the CE student.

We identified 40 universities that had complete courses in CE dedicated to stochastic theory education (or a related discipline, such as ‘‘numerical methods''). Twenty-seven of these courses (11.2% of total surveyed) were relevant to water resources or environmental engineering, while 23 courses (9.5% of total surveyed) were related to pure water resources discipline. Eighteen courses were found to be dedicated to surface water hydrology. The 27 courses and their respective instructors comprised our working set for the more detailed tier 2 survey that is described next. Table 1 summarizes the finding of the first tier of our survey.

Tier Two Survey

The 2nd tier of the survey was conducted by requesting the 27 selected instructors of courses involving stochastic theory in water resources engineering to complete the online survey form at www.surveymonkey.com. Nineteen specific questions were asked and these are shown in Appendix 2.

Our 2nd tier survey indicated that 62.5% of instructors were active users of some kind of computer-assisted technology for classroom instruction beyond the use of powerpoint or WebCT. All instructors believed that a rapid visualization system to represent the effect of input (i.e., an aspect of stochastic theory) on output (i.e., application or representation of variability) would enhance the technology as a learning tool. Surveyed instructors were also unanimous in their willingness to integrate an instruction tool that could rapidly visualize the implications of an aspect of stochastic theory for real-world examples of water resources engineering. However, 42% had some reservations on institutionalizing the use of such computer assisted instruction tool too early. Those with reservations appeared to indicate that students may not respond favorably to such a tool unless it was very user-friendly with attractive and professionally built graphics like commercial softwares.

PROOF-OF-CONCEPT OF A COMPUTER-AIDED VISUALIZATION TOOL

Overview of the Computer-Aided Visualization Tool

A proof-of-concept demonstration of the prototype technology that could be applied in water resources education has recently been completed at Tennessee Technological University. The prototype development was part of a senior-level software design project by Computer Science Majors and is named STEVE Ver 1.0 (Stochastic Theory Education through Visualization Environment; Fig. 1). STEVE is a GUI comprising a control panel (left panel of Fig. 1) where the user can key in input parameters on stochastic theory concepts. These stochastic concepts (or parameters) pertain to the stochastic model used for rainfall generation that is discussed next.

In this study, the stochastic model that was embedded in the GUI visualization tool is named ''Two-Dimensional Satellite Rainfall Error Model (*SREM2D*)'' after Hossain and Anagnostou [22]. *SREM2D* uses as input ''reference'' rain fields of higher accuracy and resolution representing the ''true'' surface rainfall process, and stochastic space-time formulations to characterize the error structure of satellite rainfall data. The major dimensions of error structure in satellite estimation modeled by *SREM2D* are: (1) the joint probability of successful delineation of rainy and non-rainy areas accounting for a spatial structure; (2) the temporal dynamics of the conditional rainfall estimation bias (rain >0 unit); and (3) the spatial structure of the conditional random deviation. The spatial structure in *SREM2D* is modeled as spatially correlated Gaussian random fields while the temporal pattern of the systematic deviation is modeled using a lag-one autoregressive process. The spatial structures for rain and no-rain joint detection probabilities are modeled using

Table 1 Summary of the Tier Survey of CE courses From World Wide Web

Total number of universities surveyed	67
Number of universities with www listing of relevant courses	57
Total number of courses identified in tier 1 survey (having the generic terms ''stochastic,'' ''statistics,'' ''numerical,'' etc., listed in course description)	241
% of graduate (dual listed) and undergraduate courses	84 (4.5) 11.5
Number of universities with integrated courses on stochastic theory or numerical methods	40
Number of dedicated courses on stochastic theory and numerical methods	84 (35%)
Number of courses on stochastic theory in water resources and environmental engineering	27 (11.2%)
Number of courses on stochastic theory in water resources only	23 (9.5%)

% is calculated by dividing the absolute number by the total number of courses surveyed (i.e., 241).

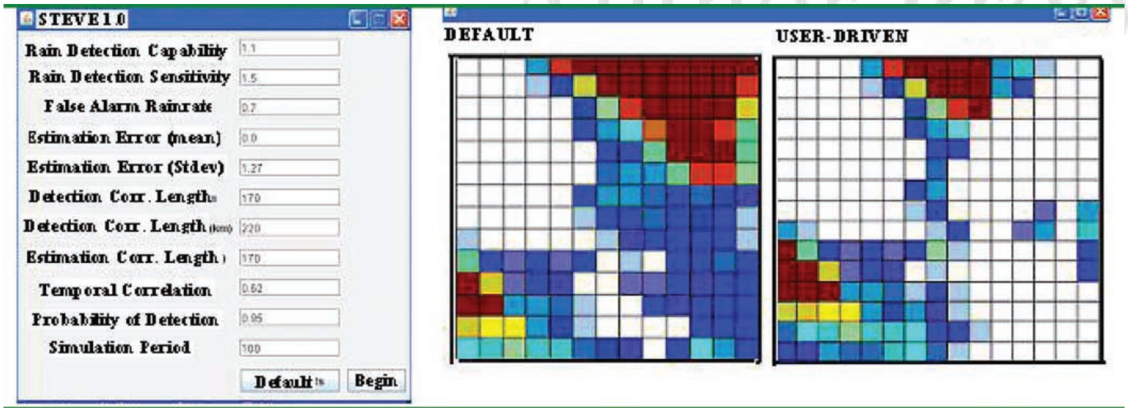

Figure 1 Screen shot of the STEVE (Ver 1.0) GUI prototype currently developed at TTU for teaching stochastic theory in the classroom. Leftmost panel is the control panel where user keys in SREM2D parameters for various stochastic theory concepts used in simulation of satellite rainfall fields. Middle and right panels visualize gridded rainfall fields. A control visualization (middle panel) for ''default'' stochastic (SREM2D) parameters is created against standard values of stochastic parameters while the right most panel visualizes the rainfall fields for user specified stochastic input. This allows the user to visually observe the effect of altering a stochastic parameter from the default value to a set of his/her choice on the right panel and thereby connect his understanding of the stochastic concept to the implication on rainfall field pattern in space and time.

Bernoulli trials of the uniform distribution with a correlated structure. This correlation structure is generated from Gaussian random fields transformed to the uniform distribution random variables via an error function transformation. *SREM2D* has nine parameters in total. Complete details on *SREM2D* are described in [22,23]. In its current formulation, STEVE assumes that the user is familiar with the SREM2D model. Hence, we suggest that the reader refers to the afore-mentioned papers in order to understand the specific stochastic theory concepts and parameters that are used in *STEVE*.

We have chosen satellite derived rainfall in STEVE as the variable to demonstrate to students the manifestation of omni-present variability in natural systems and its computational stochastic modeling for two particular reasons:

(a) Flood as a catastrophic hydrologic hazard: According to UNESCO, floods account for about 15% of the total death toll related to natural disasters, wherein more than 2,000 lives are typically lost and at least 10,000,000 people displaced annually [24]. Rainfall's intimate interaction with the landform (i.e., topography, vegetation and channel network) magnified by highly wet antecedent conditions leads to catastrophic flooding in medium and large river basins. Therefore students need to recognize the importance of rainfall as one of the primary driver that dictates the make-up of flooding overland.

(b) The emergence of high resolution global satellite rainfall data: The systematic decline of in situ networks for hydrologic measurements has long been recognized as a crucial limitation to advancing hydrologic research in medium to large basins, especially those that are already sparsely instrumented [25,26]. As a collective response, sections of the hydrologic community have recently forged partnerships for the development of space-borne missions for cost-effective, yet global, hydrologic measurements. Examples are the Hydrospheric State (HYDROS) mission for global mapping of soil moisture conditions [27], the Water Elevation Recovery (WatER) mission for surface flow measurement [28] and the GPM mission for global monitoring of rainfall [29]. There is no doubt that the scientific community as a whole will gradually become dependent on these space-borne missions for most of its data needs for hydrologic research. Thus engineering (or STEM) students must be made cognizant of the major aspects of satellite remote sensing of rainfall if an effective graduate research program is to be built in anticipation of the changing research direction encompassing proposed satellite missions.

Computer Architecture for STEVE 1.0

The Java Native Interface (JNI) language was used for communication between the Fortran code of *SREM2D* and the GUI wrapper. This way, the GUI could be executed on any operating system without the requirement of additional softwares or Fortran compilers. There were three essential software design entities: (i) *Frontend*, (ii) *Fortran Code*, and (iii) *Graph Window* (see Fig. 2). The *Frontend* entity is the main source of the software technology program (in this study, it is *SREM2D*). All calls and receiving are done within this entity in Java language. It gets the input from the data provided by the user, send that data to the *Fortran Code* for calculations, receive the calculated data (output) and then finally send that output to create and display the graph. The *Fortran Code* entity is basically the *SREM2D* model that has already been coded in Fortran 77 [22]. No tampering of the *SREM2D* code is allowed on this GUI program to preserve the theoretical consistency of the parent *SREM2D* concept that has been thoroughly verified in previous work [22]. This *Fortran Code* accepts input from the *Frontend* and sends back the calculated data for graph processing (Fig. 2). The *Graph Window* is basically the GUI of the whole program. After *Frontend* sends its inputs to the *Fortran Code* and receives the calculated data, it will then send a signal to the *Graph Window* for a rapid visualization. This entity displays a hard coded graph (control) along side a (test) graph manipulated by the user for data comparison.

The right hand side of Figure 1 represents the visualization of the output of STEVE (in this case, animated field sequence of control rainfall fields vs. animated experimental rainfall fields). The GUI preserves the user-friendliness of the visualization process because the user does not need to delve in to the complex code of *SREM2D* that is used for generation of satellite rainfall fields. Rather, the GUI simplifies the ensemble of concepts in the form of a control panel that the user can manipulate very easily. Thus, user students can be made to independently use the STEVE-GUI and observe the connection between stochastic theory and what truly happens in a real-world phenomenon.

For example, the STEVE-GUI can be used to stress the following stochastic concepts to the student body:

(a) Discrete and continuous probability density functions—implications of the choice of distribution on modeling variability of satellite rainfall estimation error.
(b) Random field generation, geostatistics and correlation length—implications on the clustering of rainy pixels, and satellite detected rainy areas over a region.
(c) Autoregressive time series analysis—implications of autocorrelation on the mean estimation error of a satellite rain field.

For example, a student may be interested in observing the effect of increasing or decreasing the correlation length of successful detection of rain by a particular satellite sensor algorithm (Passive Microwave or Infrared). The STEVE-GUI can automatically plot a two-dimensional colored contour field on the randomly generated satellite field for low and high correlation lengths wherein the student can definitively appreciate that physical meaning of "spatial structure"

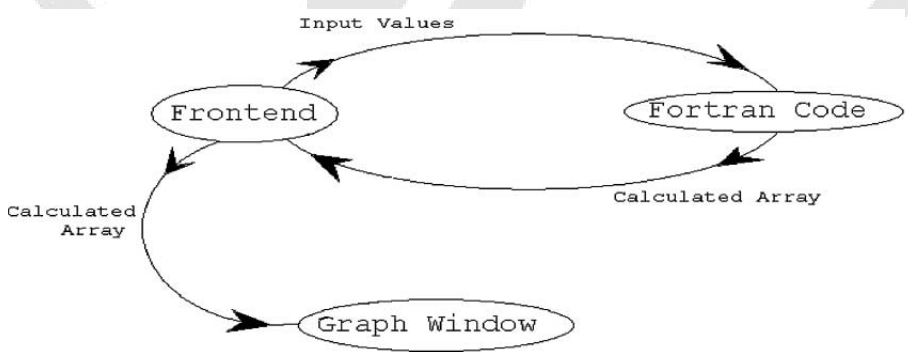

Figure 2 Entity dependency diagram for prototyping the *SREM2D*-GUI. Front end is programmed using Java Native Interfacing (JNI) language.

for modeling natural variability of satellite rain estimation systems (see Fig. 3 for a graphical example). Subsequently, the student can assess the implications of spatial structure on optimal interpolation such as random field generation. Similarly, a student may be curious about the meaning of temporal autocorrelation of estimation error (for time series analysis) and may choose to use the STEVE-GUI for contrasting values of lag-one correlation values of satellite retrieval bias. The GUI can plot the time-series (animation) of satellite rainfall fields for the two contrasting conditions thereby assisting the student in appreciating the difference in his/her choice of parameter values.

In the current development stage of STEVE, the rainfall input database is in-built in the system. However, this by no means indicates that the education system is inflexible to provide students examples of rainfall patterns of other regions easily. Certain modifications can be made relatively easily to have an extra feature in the control panel where the user-specified high quality rainfall data can be read before the *SREM2D* simulations begin.

CONCLUSIONS

We conducted a two tiered survey of the CE course curricula to gauge the general state of instruction of stochastic theory for water resources engineering. A total of 67 such university websites were surveyed. Our survey indicated that most universities offer a wide range of courses wherein concepts of stochastic theory are taught. However, the majority of the courses were mostly offered at the graduate level (84%), probably indicating the need for us to rethink our strategies for curriculum development for the 21st century. We believe it is worthwhile for the CE educators to consider creating more undergraduate variants of such courses and offer them to students early in their education experience. That way, our expectation for better trained entering graduate students for independent research in water resources engineering can be potentially increased. Among the courses that were solely dedicated to the instruction of stochastic theory or a related discipline, 11.2% (27 courses) were found relevant to water resources

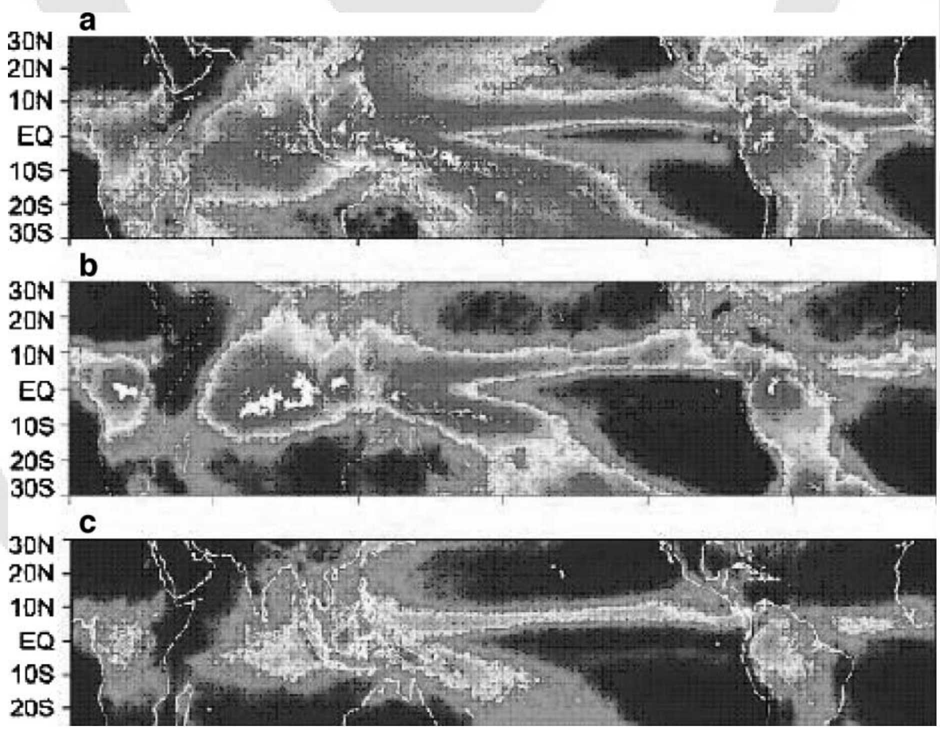

Figure 3 Graphical demonstration of the concept of ''spatial structure'' of rainfall and ''correlation length'' (a STEVE input parameter) that is used to quantify it. Uppermost panel—rainfall pattern with high correlation length (i.e., strong spatial structure or persistence). Middle panel—rainfall pattern with moderate correlation length; lowermost panel—rainfall pattern with low correlation length (i.e., insignificant spatial structure and more widespread randomness in the rainfall magnitude in space).

engineering, while only 9.5% (23 courses) were related to surface water hydrology.

Our 2nd tier survey indicated that only 62% were active users of computer-assisted technology for classroom instruction. However, there was unanimous agreement in the willingness of instructors to integrate a computer aided visualization tool that could rapidly visualize the implications of an aspect of stochastic theory in practice and connect it to the water resources perspective of the real-world. We believe that with such a visualization tool, the effectiveness of modernizing course curricula in CE for undergraduate water resources education could be made more in sync with the needs of the 21st century and that there is indeed a justification for its development. The demonstration of the proof-of-concept of the visualization tool (STEVE 1.0) using Java Native Interfacing indicated that the technology development is feasible and can be implemented easily on any classroom PC. With such an upgrade in curricula, we can hope to expect better prepared graduate students for independent research in emerging issues of water resources engineering.

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APPENDIX 1

List of Universities Surveyed in Tier 1 Search

1.	University of Vermont
2.	University of Maine
3.	University of New Hampshire
4.	University of Connecticut
5.	Yale University
6.	University of Massachusetts—Amherst
7.	University of Massachusetts—Lowell
8.	University of Massachusetts—Dartmouth
9.	Boston University
10.	MIT
11.	Brown University
12.	University of Rhode Island
13.	Princeton University
14.	Cornell University
15.	State of University of New York, Buffalo
16.	Columbia University
17.	Stevens Institute of Technology
18.	New Jersey Institute of Technology
19.	Rowan University
20.	University of Virginia
21.	University of North Carolina, Chapel Hill
22.	North Carolina State University
23.	Clemson University
24.	University of South Carolina
25.	Georgia Institute of Technology
26.	Vanderbilt University
27.	University of Tennessee, Knoxville
28.	University of Alabama
29.	University of Mississippi
30.	Mississippi State University
31.	Auburn University
32.	University of Florida
33.	University of Central Florida
34.	Florida State University
35.	University of Miami
36.	University of Kansas
37.	University of Oklahoma—Stillwater
38.	University of Oklahoma—Oklahoma City
39.	Oklahoma State University
40.	University of Texas, Austin
41.	University of Texas, San Antonio
42.	University of Arizona, Tucson
43.	New Mexico Institute of Technology
44.	University of New Mexico
45.	University of Nevada, Reno
46.	University of California, Los Angeles
47.	University of California, Berkeley
48.	University of California, Irvine
49.	University of California, San Diego
50.	University of California, Davis
51.	San Diego State University
52.	Stanford University
53.	University of Washington
54.	Oregon State University
55.	Washington State University
56.	University of Illinois
57.	Michigan State University
58.	University of Michigan
59.	Purdue University
60.	University of Cincinnati
61.	University of Ohio
62.	Ohio State University
63.	University of Wisconsin, Madison
64.	University of Delaware
65.	University of Wyoming
66.	Tufts University
67.	Syracuse University

APPENDIX 2

Questionnaire

Assessing the State of the Art of Instruction in Stochastic Theory for Water Resources Engineering. I am contacting you because World Wide Web survey of university course curriculum indicates you as an instructor for a course (graduate or undergraduate) involving components of stochastic theory in a water resources discipline. I am kindly requesting you to fill-in the attached questionnaire as part of a nation-wide survey to assess how a computer-based instruction tool could be integrated within the conventional format of teaching. Completion of the questionnaire requires mostly binary responses (YES or NO) and would take approximately 5–10 minutes.

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Please tick.

Question 1
What is the level of your course?
Answer: 1. Graduate
2. Undergraduate

Question 2
For a graduate course, is your course typically taught for entering graduate students (MS) or intended for more advanced level students (i.e., Doctoral level)?
Answer: 1. Entry-level graduate (MS)
2. Advanced-level graduate (PhD)
3. Does not matter

Question 3
For an undergraduate course, is there any prerequisite (like basic probability and statistics)?
Answer: 1. Yes
2. No

Question 4
How often is the course offered?
Answer: 1. Every semester
2. Once a year
3. Alternate years
4. Occasionally (3 or more year cycle)

Question 5
Do you follow any particular book(s) as text for class?
Answer: 1. Yes (please name the book(s)……………………………………………………)

2. No

Question 6
What is the average size of your class?
Answer: 1. 0-5
2. 5-10
3. 10-20
4. 20+

Question 7
Do you use any kind of computer-assisted technology for your instruction? (Note: this does not involve the use of powerpoint presentation or WebCT)
Answer: 1. YES
2. NO

If your answer was NO for Question#7, please proceed to the end of the survey and complete your details? Otherwise, please continue.

Question 8
Is your computer assisted technology based primarily on computer hardware features? (For example, are you using a tablet PC to increase student-teacher interaction?)
Answer 1. YES
2 NO

Question 9
If you answered YES in 8, then describe briefly the type of hardware-technology you use (Examples – Tablet PC in a wireless environment)
Answer:

Question 10
Is your computer assisted technology based primarily on software features?

Answer 1 YES
2 NO

Question 11
If you answered YES in Question 10, then, please specify the type of instruction software you use (e.g. name of the software if it is an available package).
Answer:

Question 12
Does the software connect between theory and application or is it just theory?
Answer 1 YES (application/implication)
2 NO (pure theory)

Question 13
If you answered NO in Question 12, then, would a variation of the software that puts the stochastic theory in perspective of water resources engineering systems be useful for instruction?
Answer 1 YES
2. NO

Question 14 (Answer if you replied 'YES' in Question 10)
Would you consider your computer-assisted technology as a hands-on tool? (Note a hands-on tool would be one that gives student (the object) full interactive control for its manipulation)
Answer: 1.YES
2. NO

Question 15

If your technology is based on software features, do you think a rapid visualization feature to represent the effect of input (i.e., an aspect of theory) on output (i.e., application or representation of variability) would enhance the technology as a learning tool?

Answer 1: YES
2. NO

Question 16

If your answer was YES in Question 15, would you be interested in being part of the development of such a tool?

Answer: 1. YES
2. NO

Question 17

If your answer was YES in Question 16, do you think such a tool could be made into a hands-on for students (i.e. have features that give full control to students to manipulate aspects of theory)?

Answer: 1 YES
2. NO

Question 18

If your answer was NO in Question 17, what could be the reason?

Answer 1. Students are too inexperienced to be handle such a complex computer- assisted hands-on tool.
2. Students will have an information overload in learning to manipulate the tool in addition to regular course assignments during a semester.
3. Students will not respond favorably to such a tool unless it was very user-friendly with attractive and professionally built graphics like commercial softwares.
4. I just don't think students should be allowed such interactive tools without supervision from the instructor on the definition of the object and subject.

Question 19

If such a rapid visualization software was developed for instruction of stochastic theory in water resources engineering that puts the theory in perspective of a knowledge domain (i.e., meteorology, hydrology, groundwater), would you be willing to test its effectiveness in improving student learning in your classroom?

Answer: 1 YES
2. NO

Thank you for completing the survey. I appreciate your time and effort. Please sign below and email back to fhossain@tntech.edu. Thank you!

AGREEMENT FORM

I hereby release information on the understanding that data resulting from this survey will only be generalized statistically. Publication of any specific data point concerning my response that may be considered connected to my institution would require my prior consent. I also understand any report drafted on the basis of this survey should be shared in order to maintain accuracy of the interpreted results.

I Agree I disagree

Signature

Print Name: Institution:
Date:

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