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**Abstracts of Presentations of the
Symposium on Mathematical Modeling
(15 September 2001)**

National Science Foundation

October 2002

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National Science Foundation
47/5, Maitland Place
Colombo 07
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Tel : 696771 - 3
Fax : 694754
Web : www.nsf.ac.lk

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INTRODUCTION

The Working Committee on Physical & Mathematical Sciences of the National Science Foundation (NSF) organized a Symposium on Mathematical Modeling. This full day symposium was held on 15th September 2001 at the NSF with the following aims:

- To provide a forum to discuss problems in the local industry and other relevant field situations that require mathematical modeling.
- To broaden the use of mathematical modeling to solve problems that arise in the local industry and other field situations.
- To initiate collaboration between the users of mathematical modeling in local industry/institutions and the mathematicians in universities.

The Speakers / Resource Persons of the above Symposium were,

Prof. P.W. Epasinghe (*Professor of Mathematics - University of Colombo / Chairman - National Aquatic Resources Research & Development Agency*)

Dr. R.P.U. Karunasiri (*Department of Physics - University of Peradeniya*)

Dr. B.R.S.B. Basnayake (*Meteorologist - Department of Meteorology*)

Mr. S.D.P.J. Dampegama (*Superintendent of Surveys - Institute of Surveying & Mapping, Diyatalawa*)

Mr. S.P.M.G. Illukkumbure (*Manager - Quality Assurance, Lanka Walltile Ltd., Balangoda*)

Dr. Jagath Wijerathna (*Department of Mathematics, University of Colombo*)

Dr. Keerthi Premadasa (*Department of Mathematics - University of Colombo / Programme Director - Informatics Institute of Technology*), and

Dr. A.A.S. Perera (*Department of Mathematics - University of Peradeniya*)

INTRODUCTORY REMARKS

Prof. P.W. Epasinghe

Department of Mathematics - University of Colombo

Prof. Epasinghe started his presentation describing the historical background of mathematical modeling through some examples. He then went on to explain how modeling evolved up to the present situation. A flow chart that could be used to model, solve, and interpret the results of real world problems was also presented.

In conclusion, Prof. Epasinghe mentioned his personal contribution to mathematical modeling locally, both in the development of the undergraduate curriculum and in research.

ABSTRACTS

Mathematical Modeling in Meteorology

Dr. B.R.S.B. Basnayake

*Centre for Climate Change Studies - Department of Meteorology,
Colombo 07*

Mathematical modeling involves various sectors such as industry, engineering, oceanography, meteorology etc. Now it is being popularized among the scientific community in Sri Lanka with different types of applications.

Mathematical modeling in Meteorology has begun in 1955 by Pearce who was the first to make some effort to integrate a non-linear model to investigate the behaviour of the atmosphere. This is now extensively being used in Meteorology with various applications viz., short-range weather forecasting, medium-range weather forecasting, long-range weather forecasting, storm surge forecasting, cyclone track forecasting etc. Basically it integrates a set of closed hydrodynamic equations with proper initial and boundary conditions using iterative numerical methods. Numerical methods are used due to the non-linearity involved in the partial differential equations. Such integration using numerical methods is called Numerical Weather Prediction (NWP). Numerical solutions are greatly dependent on the initial conditions or initial state of the atmosphere, choice of boundary conditions and numerical methods (finite differencing or finite element method). There are several types of mathematical models in meteorology depending on the temporal and spatial variation of the model domain. Limited Area Model (LAM) is one such model, which is used to forecast daily weather (i.e. short-range weather). General Circulation Model (GCM) is another type of model, which is being used to forecast medium-range / long-range weather over an area of interest. Meso-scale models are also used to predict small-scale weather phenomena such as thunderstorms and also to predict atmospheric effluents in industrialized areas.

Mathematical Modeling : A Physicist's Views

Dr. R.P.U. Karunasiri

Department of Physics - University of Peradeniya

What is the definition of the term mathematical modeling? Author is reluctant to define it and was unable to find a universally accepted definition for it. On the other hand it is perhaps fair to assume that the reader in some sense knows what it means.

Mathematics is one of the most useful tools available for a physicist. We define the role of physics as to *observe* and to *understand* natural phenomena. At which point is that it is possible to claim that the understanding is complete? We state that once the *laws* governing the phenomena are established and are put into the minimum in number and general in validity, it is reasonable to claim that an understanding is complete. The specification of the laws is carried out using the language of *mathematics*. Based on this point of view, it is quite natural to state that once the mathematical model representing a given phenomenon is specified, it is understood as well.

Newton's second law in classical mechanics, Maxwell's equations in electromagnetism, the laws of Thermodynamics, Fundamental postulates in Statistical Mechanics and Schrodinger equation in wave mechanics are examples that belong to the above category. However, it is *not* that all the postulates in physics are expressed as equations. Principle of relativity, i.e. the first postulate of special relativity, can be given as one such exemption.

P.A.M. Dirac's Hilbert space formalism of *quantum mechanics* and Einstein's theories of *relativity* are two of the most beautiful mathematical models ever created. While the former is aimed at explaining phenomena observed in the microscopic world, latter does the same at the cosmic level.

The application of mathematical modeling is by no means limited to the field of physics. Some of its applications are listed in Table I.

Table 1. Applications of Mathematical Modeling

AREA	APPLICATION
differential equations	aerodynamics, finance
fluid dynamics	aircraft and automobile industry
geometry	computer aided design
algebra & number theory	cryptography
discrete mathematics	communication and information theory
formal systems & logic	computer security
nonlinear control	operation of mechanical/electrical systems
optimization	asset allocation
statistics	design of experiments, analysis of data sets
parallel algorithms	weather modeling, crash simulation

The reader may glimpse into the capabilities and the various fields of applications of mathematical modeling through one of the recently developed techniques called **wavelet transform (WT)**. This method depends heavily on mathematical modeling and may be defined as the representation of a discrete signal or an image using *wavelet function* at different locations and scales, computed using the fast pyramid algorithm. WT is very similar to classical Fourier transform (FT) method and is most successful where FT fails, i.e. at signal discontinuities such as edges of an image.

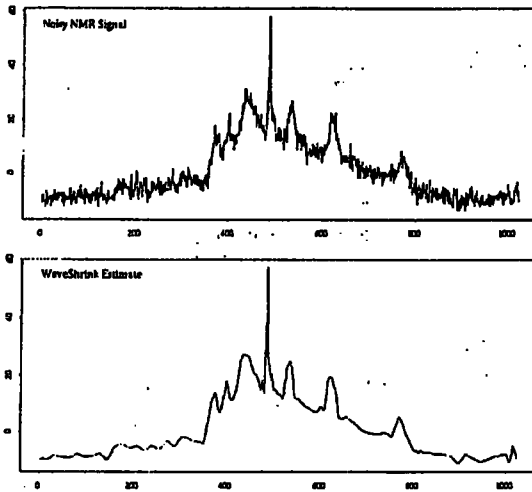
Data compression without sacrificing the quality of the images, Removal of the noise from signals and images and Rapid prototyping are few of the most attractive features of this technique.

Pictures at the end of this article (Figures 1,2 & 3), representing applications of WT in geology, spectroscopy and medicine, show the remarkable capabilities of this technique.

Mathematical modeling combined with the knowledge and the creativity of its user has unlimited potential for applications within and outside the field of physics. It is the message that we try to bring forward with this short article.

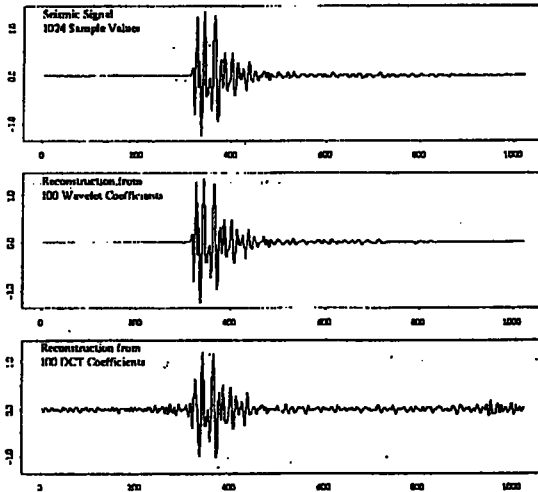
Finally, the author very much admires the efforts of the organizers of this workshop who work diligently toward creating mechanisms for

connecting mathematicians with others working in different academic fields as well as in industry, for their mutual benefit.



A noisy nuclear magnetic resonance (NMR) signal [top] is compared with the same signal without the noise [bottom]. Setting to zero the coefficients that do not exceed a certain threshold and then inverting the transform gets rid of the noise in the wavelet domain. An important feature of the noise-removal algorithm is its ability to remove noise while simultaneously preserving non-smooth features, such as the large spike in the NMR signal. Data are from the laboratory of Adrian Maudsley, University of California, San Francisco.

Figure 1. Application of wavelet transform in geology



A seismic signal with 1024 sample values [top] is reconstructed from 100 wavelets [middle]. It is also shown reconstructed from 100 cosine functions [bottom] using the discrete cosine transform (DCT). Widely used in signal and image compression, the DCT represents signals as sums of cosine functions. The wavelet reconstruction is visibly better.

Figure 2. Application of wavelet transform in spectroscopy



One of the pictures above is a digitized magnetic resonance image. The other is its reconstruction from a file compressed to one

twelfth of its original size by using a wavelet based lossy compression algorithm. More important, the reconstruction of the

image retains the features needed for making medical diagnoses. So which image is which? The original is shown on the left.

Figure 3. Application of wavelet transform in medicine

Mathematical Modeling for Determination of Original Size & Shape of the Abhayagiriya Stupa

S.D.P.J. Dampagana

Institute of Surveying & Mapping, Dryatalawa

This paper presents the mathematical model developed to determine the original size of the Abhayagiriya stupa at Anuradhapura. Determination of the radius and the centre of the stupa was computed using the mixed model observation equations of general least square principle. The radius of the stupa was determined by taking the coordinates of the old plasters available on the outer surface of the dome. Observations were taken with respect to a three dimensional Cartesian coordinate system. Radius and the center of the stupa were computed to an accuracy of $\pm 5\text{cm}$ due to the advance technology utilized in field procedures and the computation methodology. The center of the Koth Kerella was also determined using the same technology. The shape was determined by best fitting curve to the old plaster / bricks existing on the stupa.

Process Control in Tile Manufacturing

S.B.M.G. Illukkumbure

Lanka Walltile Ltd., Balangoda

This presentation starts with an introduction to the Company, Lanka Walltiles Ltd., outlining its history, products and market. The production process of wall tile manufacture was discussed with emphasis on process control, process capability measurements, techniques used for defect analysis and market analysis. The degree of mathematical applications used for manufacturing many, vary according to the nature of product. Through this Symposium, it is expected to refine and improve the following mathematical modeling techniques presently used for process control : Mean charts plotted with daily averages of sample readings, Monthly calculation of process capability and process capability index, Control of finished product, and Weekly and monthly analysis of product defects.

Some Down to Earth Applications in Mathematical Modeling

Dr. Jagath Wijerathna

Department of Mathematics - University of Colombo

Shoe Sole Fitting Problem

In the shoe production industry, in general, shoes and the soles are produced by two different producers. When a shoe producer wants to find appropriate sole for a particular shoe model he looks for the sole producers. Usually soles are not specially made for particular type of a shoe model. One type sole may be used for various models of shoes. This is due to raisein transfer moulding process involved in the sole production. Therefore, it is quite interesting and industrially substantial question to investigate how to find an optimally fitting available sole in a short time for given model of a shoe. Some sole manufactures do it manually. But this cost a lot of time and need well-experienced personnel. In other words, the task is to find out the most suitable sole for a given shoe from an existing collection. To address this problem, one can construct a mathematical model using undergraduate level mathematics and realize it in computer. Our group proposed the following principal steps.

- Set up a database of available soles.
- Set up a coordinate system to place the given sole shape and elements of the database considering characteristics of the human foot.
- Introduce a mathematical measure to compare the given shape with elements of the database.
- This process can be implemented using MATLAB without much effort and results are quite acceptable.

Optimal Design of an Industrial Oven

There is always a demand to improve an industrial manufacturing process. For example, in the bakery industry which uses an oven with two different temperatures at the bottom. To achieve these two different temperature levels one could control the shape of the top and the heat sources. Radiative heat exchange equations are used to model this process, as it is the most significant factor in the process.

One way of attacking this problem is to consider a continuous heat source over the top of the oven and find the numerical solution of the governing equations. Observing the behaviour of this continuous source one can locate the suitable positions of discrete sources. This procedure is leading to quite acceptable results. Heat source positioning is only one parameter in the problem but there are many more to tune up and optimize the process.

This work is done in the corporation of the mathematical modeling seminar group at University of Kaiserslautern.

Mathematical Software for Use in Mathematical Modeling

Dr. Keerthi Premadasa

Department of Mathematics - University of Colombo

The packages MATLAB, MAPLE, MATHEMATICA, GAP, Cayley, Macarley were discussed generally explaining the fact that MATLAB, MAPLE and MATHEMATICA fall into the general purpose mathematical software category, while GAP (Finite Groups), Cayley (Infinite Groups), Macarley (Rings) are software packages which cater to specific mathematical disciplines.

An example of a problem with unknown interest annuity was solved using MAPLE's polynomial function command. The ease of computation was also discussed in contrast to the tedious manual method.

A second example of a portfolio analysis problem was solved using MATLAB, which involves expected returns and the covariance matrix of returns as input, again highlighting the ease in which the analysis was made using MATLAB financial tools.

DISCUSSION

Chaired by

Dr. A.A.S. Perera

Department of Mathematics - University of Peradeniya

After making the welcoming remarks, the Chair invited the participants for a discussion on the following issues :

1. **how to increase the interaction between teachers and others using Mathematics, and**
2. **how and what should be taught as mathematical modeling at universities**

The following decisions were agreed upon regarding the first issue :

- To create a website for Mathematical Modeling activities of Universities for the purpose of posing and solving related problems. The participants decided that either the PGIS, University of Peradeniya or the NSF should host the web site.
- To publish a brochure highlighting the day's activities to be circulated among interested companies.
- Start an Institute of Mathematical Science with the coordination of the PGIS / the NSF. The institute should have facilities for consultancy and publications.

Regarding second issue, the participants agreed on the following :

- Using computers for Undergraduate teaching to make the subject more attractive to potential students.
- Popularizing Mathematics through the use of real life situations in modeling courses.
- Initiating University Industry links through the UGC.
- Marketing the resources to private and public enterprises.
- Introducing new subjects with Mathematical applications like Financial Mathematics, Econometrics and Actuarial studies, etc.
- Contacting graduates already employed in industries to improve dialog between industry and academics.

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LIST OF PARTICIPANTS

<u>Name</u>	<u>Institute</u>
NARA	
1 Mr. S.W.S. Weerasinghe	National Hydrographic Office
2 Mr. W.A. Ariyawansa	"
3 Mr. S. Haputhantri	"
4 Mr. J.K. Rajapaksha	Oceanography Division
5 Mr. S.U.P. Jinadasa	"
6 Mr. W.D.A.J.P. Wijendra	"
University of Colombo	
7 Mr. W.A.S.P. Weeratunga	Department of Commerce
8 Mr. S.S.N. Perera	Department of Mathematics
9 Ms. M.J.L. Mendis	"
10 Ms. L.C. Edussuriya	"
11 Dr. C.J. Jayawardene	"
University of Kelaniya	
12 Dr. M.A.U. Mampitiya*	Department of Mathematics
13 Dr. M.D. Devendra	"
University of Peradeniya	
14 Prof. M.A. Careem*	Department of Physics
15 Prof. B.S.B. Karunaratne*	"
16 Dr. D.B. Daundasekara	Department of Mathematics

17 Dr. J.C.N. Rajendra*

18 Dr. S. Kanaganathan

19 Mr. V. Jayanthiran

20 Ms. M. Mehala

21 Mr. P. Paramathevan

22 Ms. J. Shanmuganatan

23 Ms. J. Thangavadivel

24 Dr. T. Sritharan

Eastern University

Department of Physics

Department of Mathematics

”

”

”

”

”

”

Open University of Sri Lanka

25 Dr (Ms). W.C.W. Perera

Dept. of Math. & Comp. Sci.

26 Mr. U. Angamma

”

27 Mr. S.J.R. Samaratinga

”

28 Mr. K.A.S.N. Fernando

”

University of Ruhuna

29 Dr. J.R. Wedagedara*

Department of Mathematics

30 Mr. N. Yapage

”

31 Mr. L.W. Somathilake

”

32 Dr. J.M.J.J. Peiris

”

33 Dr. L. Jayasekera

”

34 Mr. M.P.A Wijesiri

”

Uni. of Sri Jayewardenepura

35 Prof (Ms). S. Weerakoon

Department of Mathematics

36 Dr (Ms). M. Liyanage

”

Wayamba University

- 37 Ms. W.T.P.S. Fernando Department of Mathematics
38 Ms. G.S. Francisco ”
39 Mr. P.M.N. Dharmawardane ”
40 Mr. S.S.U.R. Fernando ”

University of Jaffna

- 41 Mr. P. Ravirajan Department of Physics

- 42 Mr. B.J.P. Mendis Survey Department

- 43 Mr. N.P.K. Medagoda Informatics Inst. of Tech.

- 44 Dr. A.W. Mohottala*

(* Member of the Working Committee on Physical & Mathematical Sciences of NSF)