Industrial Mathematics
and
Study Groups with Industry

Prof. Dr. Erhan Coşkun
Karadeniz Technical University
erhan@ktu.edu.tr

December 18, 2012
METU, Institute of Applied Mathematics

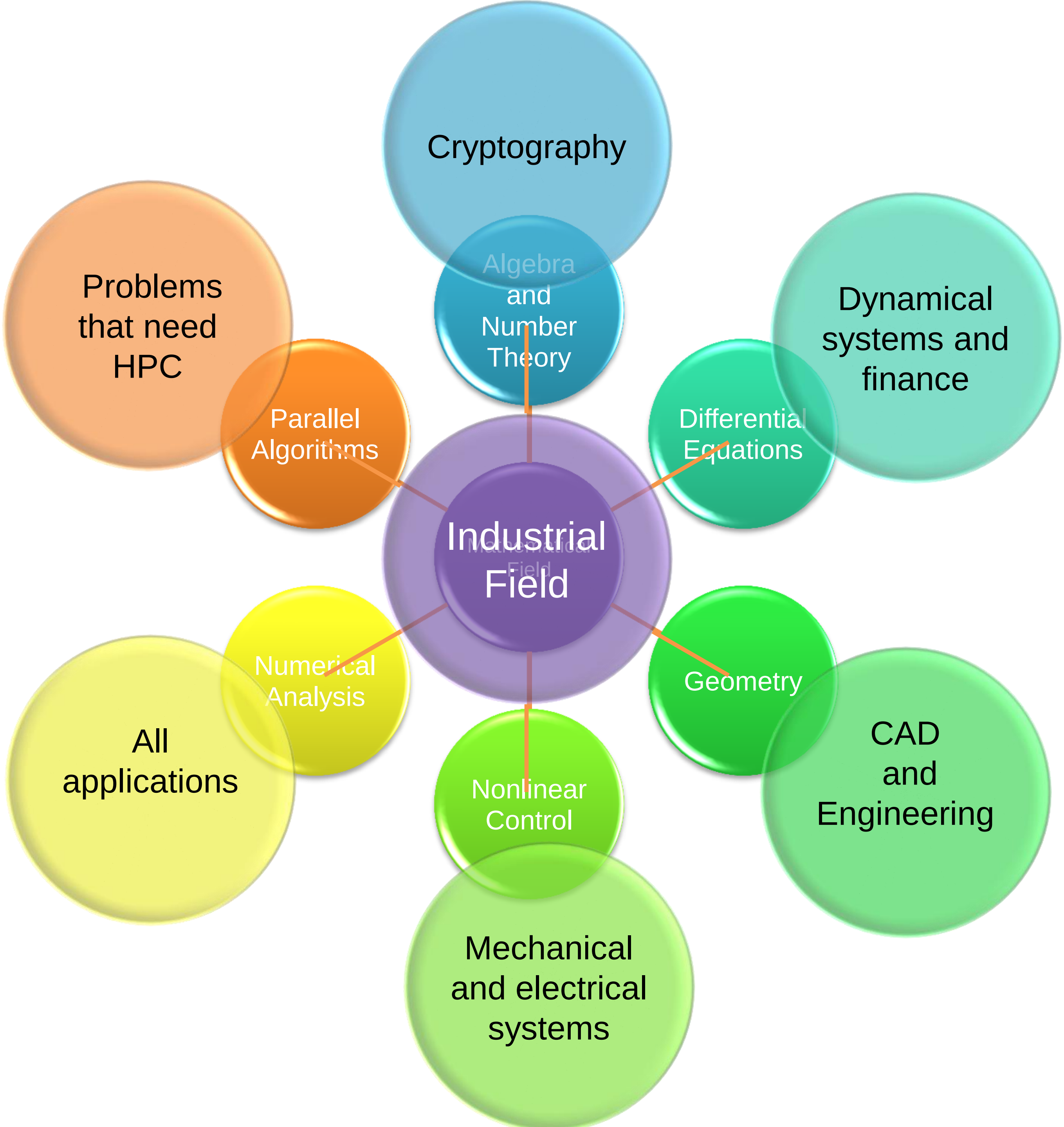
Outline

- Industrial Mathematics
  - Mechanisms for promoting Industrial Mathematics
  - Common Features of industrial problems
- CASE Studies from recent Study Groups
- Shall we continue with study groups?

Terminology

- Industrial mathematics
  - Development and analysis of mathematical models for the problems of industry (A. Friedman)
- Industrial mathematician
  - Uses various mathematical tools to analyze industrial problems.
  - The focus is the problem, not a field which may have potential applications

Industrial



Mathematics

industrial mathematics

Yaklaşık 6.660.000 sonuç bulundu (0,24 saniye)

Industrial Mathematics | Professional Science Master's Program
psm.rutgers.edu/.../**industrial-mathematics** - Bu sayfanın çevirisini yap
Industrial Mathematics. Printer-friendly version. Concentration: **Industrial Mathematics** - Camden, New Jersey Overview: **Industrial Mathematics** is a branch of **...**

Applied **mathematics** - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Applied_**mathematics** - Bu sayfanın çevirisini yap
The use and development of mathematics to solve industrial problems is also called "**industrial mathematics**". The success of modern numerical mathematical **...**
History - Divisions - Utility - Status in academic departments

Industrial Mathematics - Overview - Open Innovation
https://connect.innovateuk.org/web/**mathsktn**
02.58PM. Judy Reynolds has created a new post titled New opportunity at BT, in the **Industrial Mathematics** sKTP-Official Sub-Group. 12.53PM. 12 September **...**

SIAM: Society for **Industrial** and Applied **Mathematics**
www.siam.org/ - Bu sayfanın çevirisini yap
Provides information on **mathematics** related books, journals, and conferences. Membership information is also available.

MS in **Industrial Mathematics** - MSU Math Department - MSIM
www.**math**.msu.edu/.../msim/Default.aspx - Bu sayfanın çevirisini yap
The goal of the Professional Science Master's (PSM) in **Industrial Mathematics** (a.k.a. MSIM) program is to produce generalized problem solvers of great **...**

Industrial Mathematics - Department of Mathematics and Statistics **...**
www.**mathstat**.strath.ac.uk/.../**industrial_mat**... - Bu sayfanın çevirisini yap
3 Jul 2009 – **Industrial Mathematics** is using mathematics to solve industrial problems, study processes and understand phenomena. It is an attitude of mind, **...**

Springer

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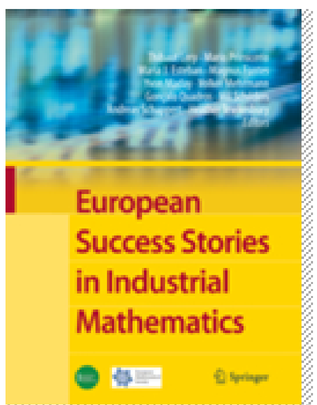


European Success Stories in Industrial Mathematics

Lery, T.; Primicerio, M.; Esteban, M.J.; Fontes, M.; Maday, Y.; Mehrmann, V.; Quadros, G.; Schilders, W.; Schuppert, A.; Tewkesbury, H. (Eds.)

1st Edition., 2011, XII, 136 p. 200 illus., 185 in color.

Read online

Available Formats:

ECMI
European Consortium for Mathematics in Industry

http://www.ecmi-indmath.org/

European Consortium for Mathematics in Industry

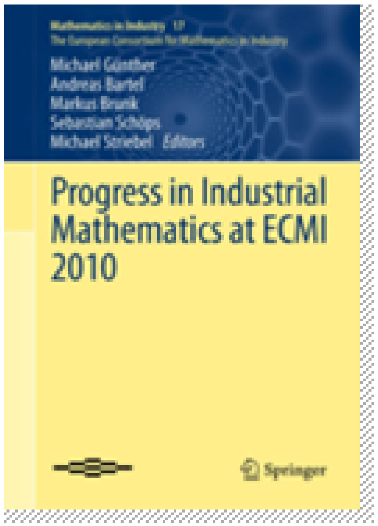
The European Consortium for Mathematics in Industry (ECMI) is a consortium of academic institutions and industrial companies that acts co-operatively to promote the following aims:

- To promote and support the use of mathematical models in any activity of social or economic importance.
- To educate Industrial Mathematicians to meet the growing demand for such experts.
- To operate on a European scale.

Mathematics plays a key role in technology, economics and lifesciences and industry is increasingly dependent on mathematical expertise. ECMI aims to support European industry in the development of technological innovations and the promotion of the Europe 2020 Agenda for smart, sustainable and inclusive growth.

ECMI is run by a Council made up of representatives of 18 European countries which supports a network of institutional members.

The Education Committee coordinates the training of industrial mathematicians via masters courses, modelling weeks, summer schools and the exchange of students and teachers.



Progress in Industrial Mathematics at ECMI 2010

Series: » Mathematics in Industry, Vol. 17
Subseries: » The European Consortium for Mathematics in Industry

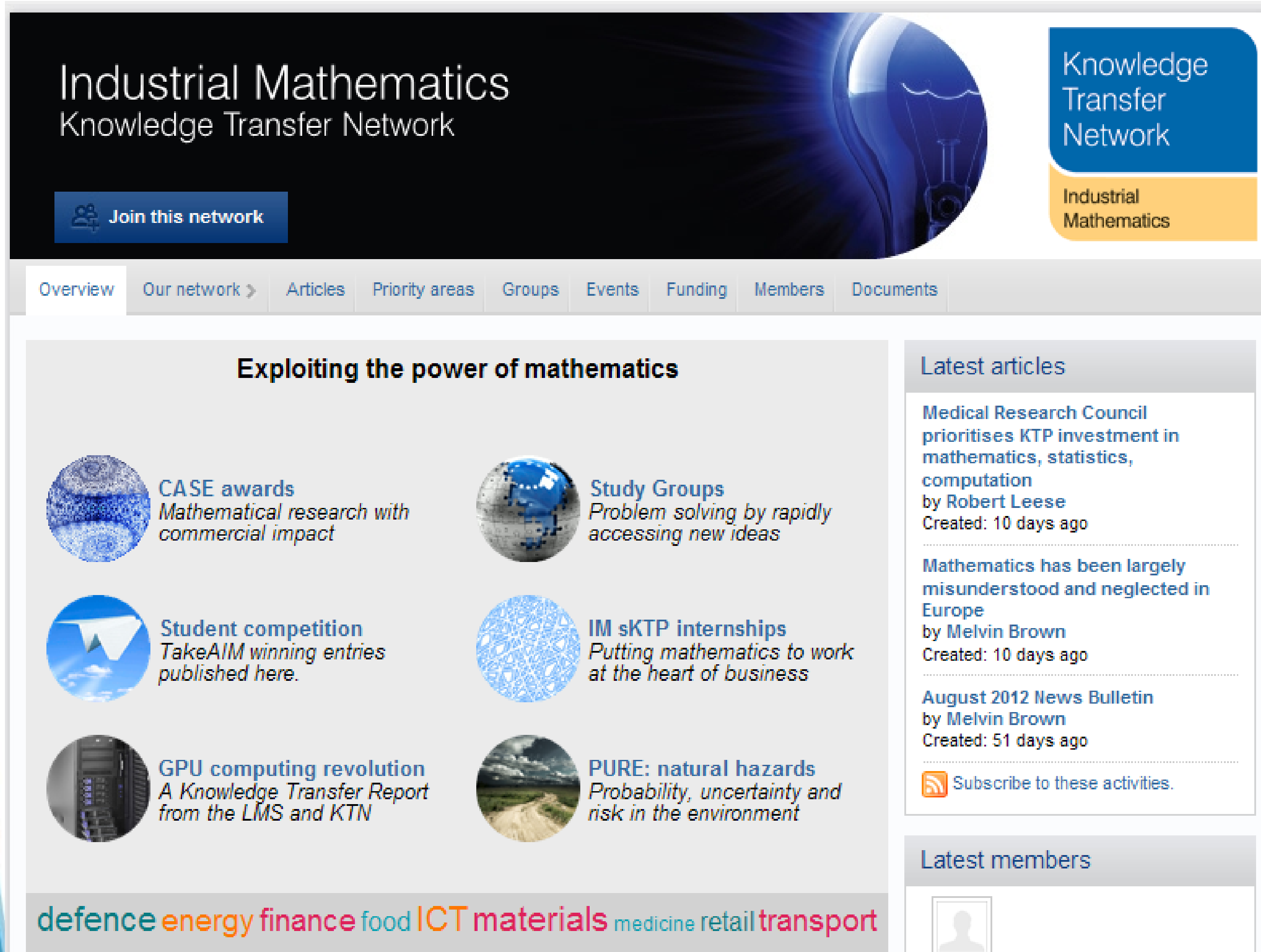
Read online

Günther, M.; Bartel, A.; Brunk, M.; Schöps, S.; Striebel, M. (Eds.)

2012, 2012, XIII, 667 p. 194 illus., 71 in color.

Available Formats:

Hardcover
ISBN 978-3-642-25099-6
Usually dispatched within 3 to 5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Student competition
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IM sKTP internships
Putting mathematics to work at the heart of business
GPU computing revolution
A Knowledge Transfer Report from the LMS and KTN
PURE: natural hazards
Probability, uncertainty and risk in the environment
defence energy finance food ICT materials medicine retail transport
Latest articles
Medical Research Council prioritises KTP investment in mathematics, statistics, computation
by Robert Leese
Created: 10 days ago
Mathematics has been largely misunderstood and neglected in Europe
by Melvin Brown
Created: 10 days ago
August 2012 News Bulletin
by Melvin Brown
Created: 51 days ago
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Country	Centre
Australia	**Centre for Industrial and Applied Mathematics (CIAM)**, Adelaide
Austria	**Industrial Mathematics Competence Center (IMCC)**, Linz
Canada	**Institute of Industrial Mathematical Sciences (IIMS)**, Winnipeg
China	**Basement for Mathematical Modelling**, Zhejiang University, Hangzhou
	"Fudan Industrial and Applied Mathematics ..." (FIAMP), Shanghai
Germany	**Institute for Algorithms and Scientific Computing (SCAI)**, Bonn
	Institute für Techno- und Wirtschaftsmathematik (ITWM), Kaiserslautern
	MATHEON, Berlin
	Weierstrass Institute for Applied Analysis and Stochastics (WIAS), Berlin
	Zentrum für Technomathematik (ZeTeM), Bremen
India	**Industrial Maths Group (IMG)**, IIT Bombay
	Gujarat Institute for Industrial Mathematics (GI^2M), Baroda
Ireland	**Mathematics Applications Consortium for Science and Industry (MACSI)**, Limerick
Italy	**Advanced Applied Mathematical and Statistical Sciences (ADAMSS)**, Milano
	Innovazione Industriale Tramite Trasferimento Tecnologico (I^2T^3), Florence
	Laboratory for Modeling and Scientific Computing (MOX), Milano
Japan	**Mathematical Research Center for Industrial Technology (MRIT)**, Fukuoka
Netherlands	**Laboratory for Industrial Mathematics Eindhoven (LIME)**, Eindhoven
New Zealand	**Centre for Mathematics in Industry (CMI)**, Auckland
Norway	**Centre of Mathematics for Applications (CMA)**, Oslo
Spain	**Centro de Supercomputación de Galicia (CESGA)**, Santiago
Sweden	**Fraunhofer-Chalmers Research Centre for Industrial Mathematics (FCC)**, Gothenburg
UK	**Oxford Centre for Industrial and Applied Mathematics (OCIAM)**, Oxford
USA	**Center for Industrial Mathematics (CIM)**, Milwaukee
	Center for Industrial Mathematics and Statistics (CIMS), Worcester
	Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), Rutgers
	Institute for Mathematics and its Applications (IMA)
	Interdisciplinary Mathematics Institute (IMI), South Carolina

Mathematics in Industry
Information Service

Training Courses

This list contains current courses for graduates and undergraduates which are focused on industrial applications and all have industrial projects as part of the curriculum.

Country/Region	Course	Duration
Canada	**MSc in Applied & Industrial Mathematics**, York University	1-2 years
Germany	**Technomathematik**, Bremen (**Google translation**)	
India	**MSc in Industrial Mathematics and Scientific Computing**, Madras	
Ireland	**MACSI MSc in Mathematical Modelling**, Limerick	1 year
Japan	**Graduate School of Mathematics**, Kyushu University	2 years
The Netherlands	**Industrial and Applied Mathematics**, Eindhoven (3 Master degrees)	
New Zealand	**MSc in Industrial Maths and Statistics**, Massey Albany	
Norway	**Masters in Industrial Mathematics**, NTNU	5 years
UK	**MSc in Modern Applications of Mathematics**, Bath	1 year FT or 2 years PT
	MSc in Mathematical Modelling and Scientific Computing, Oxford	1 year
	MSc in Mathematics of Scientific and Industrial Computation, Reading	1 year
USA	**Harvey Mudd College**, Claremont	
	Professional Master of Science in Industrial Mathematics, Michigan	

Applications Involvement Component equals more success for Ph.D. students in math at NIU

Linda Sons

Most **Ph.D. students in math** never think about working for a major corporation or federal agency as part of their program. Doctoral students normally worry about qualifying exams, writing their dissertations and obtaining careers in academia.

At NIU, however, students are involved in a unique plan of studies.

The Applications Involvement Component (AIC) of the math Ph.D., created in the early 1990s under the direction of **Linda Sons**, has now become "a model for institutions across the US."

So says professor **Avner Friedman**, a recognized authority in the world of applied mathematics, founding director of the Mathematical Biosciences Institute, member of the National Academy of Sciences, past president of the Society of Industrial and Applied Mathematics (SIAM) and past president of the Society of Mathematical Biology.

NIU alums agree.

NIU Today article about the departmental **Applications Involvement Component** (AIC) program

http://www.math.niu.edu/

Study Groups

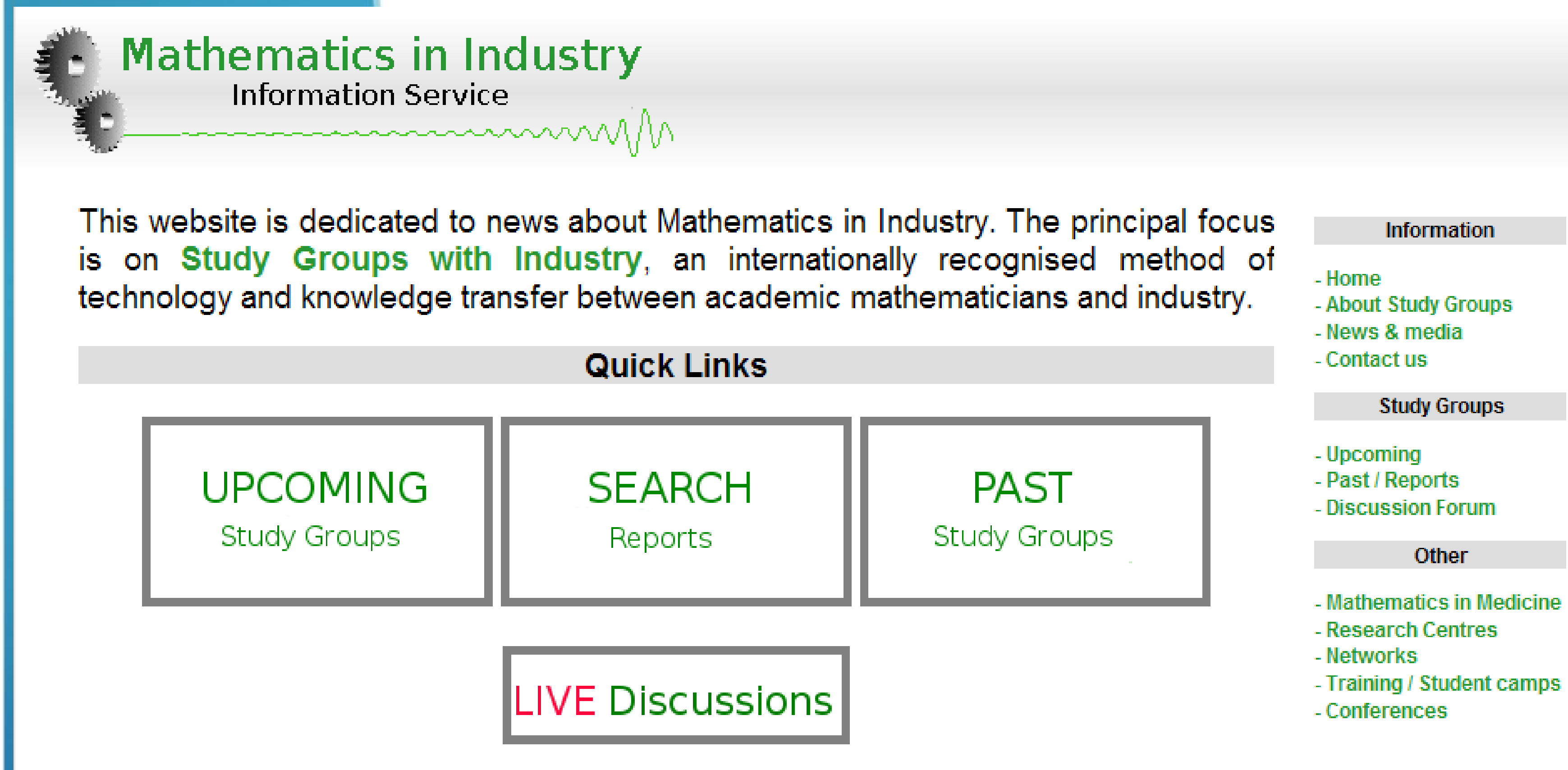
European Study Groups with Industry

Study Groups with Industry are an internationally recognised method of technology transfer between academic mathematicians and industry. These week long workshops provide a forum for industrial scientists to work alongside academic mathematicians on problems of direct industrial relevance.

The success of the Study Groups' unique format, which uses problems presented by industry as a basis for mathematical research, is demonstrated by the extent to which it has been copied around the world and is now extending into other areas where mathematics may be applied. The **European Study Groups with Industry** (ESGI) started with the first Study Group in Oxford in 1968 and now there are 5-7 meetings held annually in different European countries.

The website www.maths-in-industry.org provides information about upcoming Study Groups and also contains a repository of the reports on the problems from many of these meetings.

http://www.maths-in-industry.org/



Technical Reports

Mathematics in Industry

The International Study Groups Website

Browse by Industrial Sector and Year

Please select a value to browse from the list below.

- Problem Area (530)
  - Aerospace and defence (34)
  - Discrete (22)
  - Energy and utilities (87)
  - Environment (24)
  - Finance (33)
  - Fluids (9)
  - Food and Drink (33)
  - Information and communication technology (70)
  - Machines / Production (5)
  - Materials (164)
  - Medical and pharmaceutical (51)
  - None/Other (90)
  - Retail (16)
  - Social (5)
  - Sports (2)
  - Transport and Automotive (59)

Technical Reports

Mathematics in Industry
The International Study Groups Website

Jump to: A | B | C | D | F | G | H | J | K | M | P | T

Number of items: **19**.

A

A., Crosby and N., Deacon and J., Dewynne and A., Lacey and W., Lee and J., Ockendon and R., Whittaker (2011) Efficient Si-melting (PLEASE EMAIL david.allwright@industrialmaths.net FOR A COPY). [Study Group Report]

B

Bohun, C. Sean (2011) Modelling mass transfer in a rotating disk reaction vessel. [Study Group Report]

C

Coskun, E. (2011) Initialization Strategy for Nonlinear Systems. [Study Group Report]

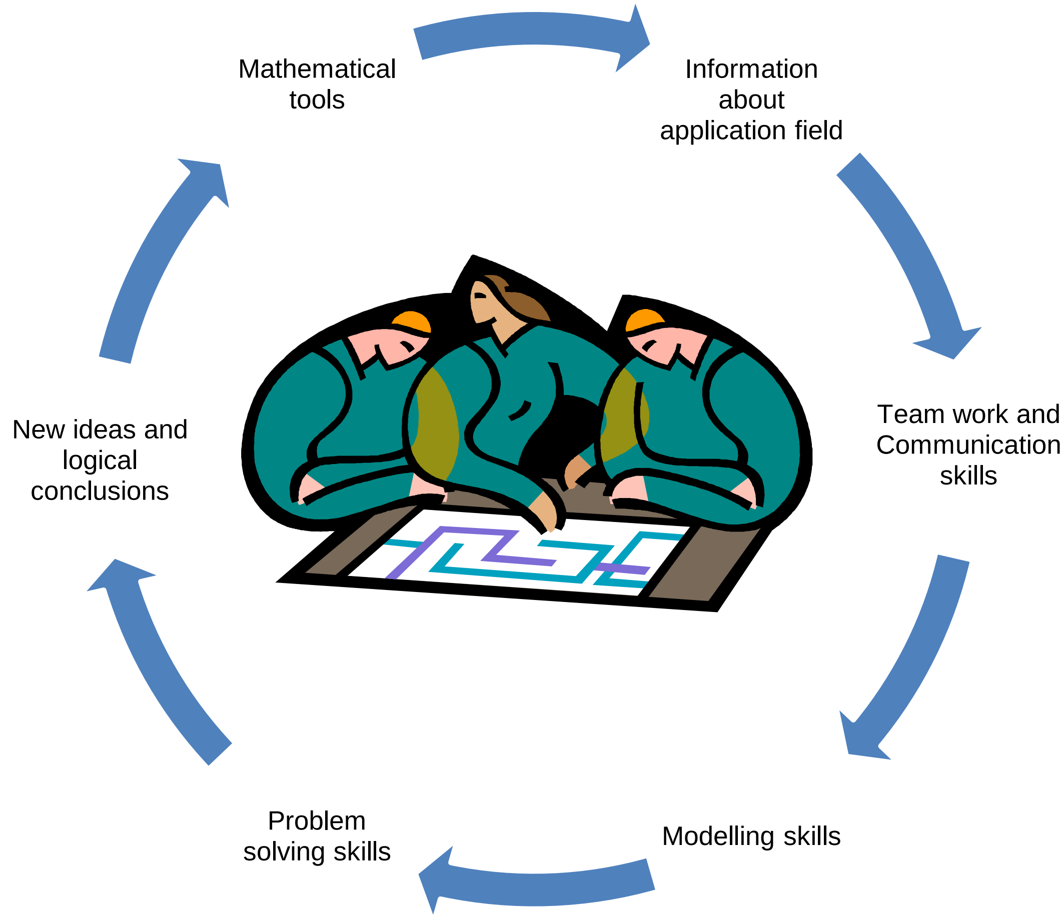
D

D., Allwright (2011) Interpreting pharmaceutical screening test results. [Study Group Report]

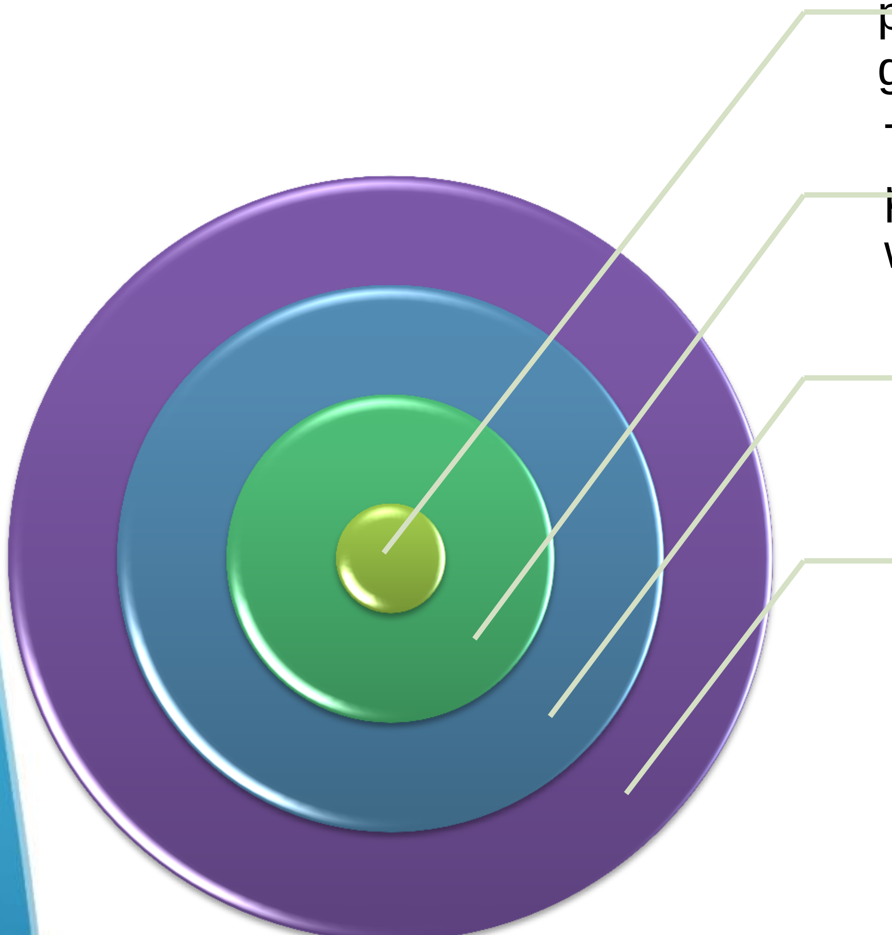
An approach for an industrial problem

- Determining the industrial problem
- Mathematical statement
- Development of appropriate model
- Analysis
- Interpretation and conclusions
- Revision of the model (if needed)

Required knowledge and skills

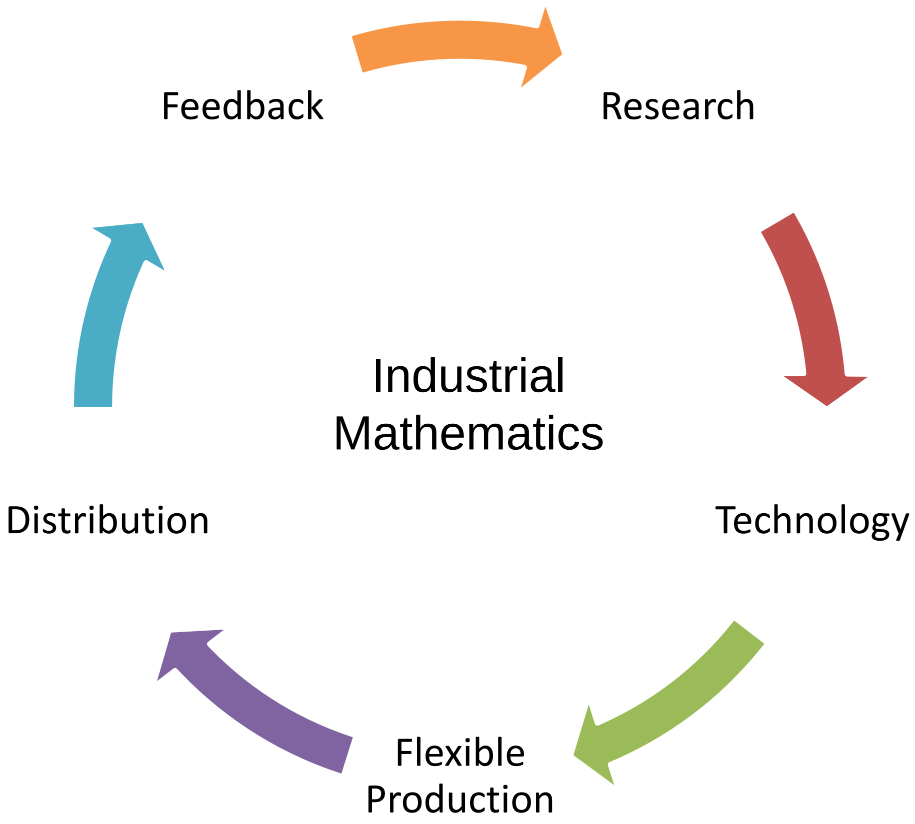


Training stages of an Industrial Mathematician

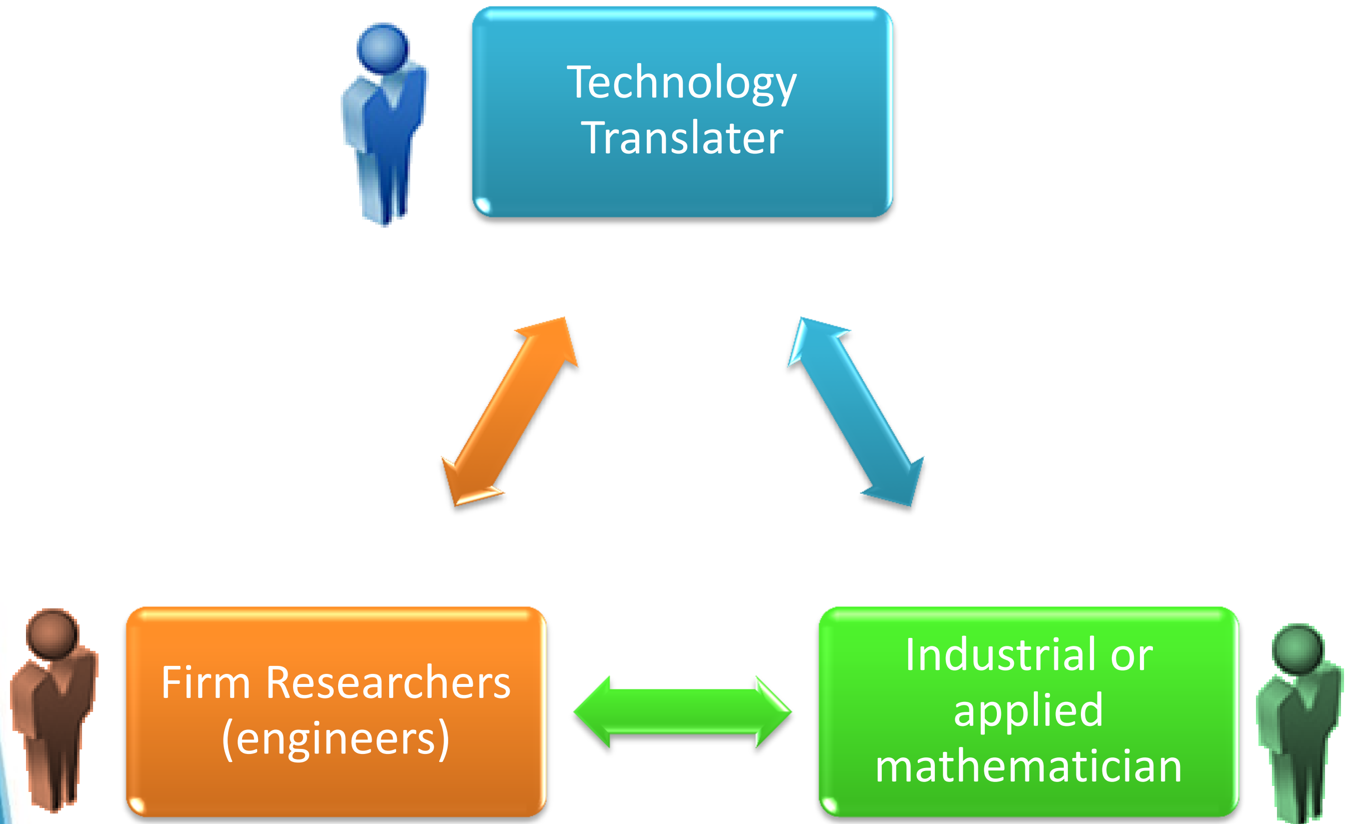


- Industrial problems(study groups)
- Team work on small problems(modelling weeks)
- Knowledge on basic application fields
- Mathematical tools including Ode’s, Pde’s, Optimization, Numerical analysis, etc.

Flexible Production Model



Industry-Mathematics Collaboration in UK



Academic Organizations

- SIAM **www.siam.org**
- ICIAM(International Consortium for Industrial and Applied Mathematics)

  www.iciam.org
- ECMI(European Consortium for Mathematics in Industry)

  www.ecmi-indmath.org
- KTN, Smith Institute(UK), Matheon(Germany), MITACS(Canada),
- TUBITAK(general science and engineering: encourage, support)

Common features of Industrial Problems

Complex Systems

- Travel(for example)
  - Determining flight destination
  - Flight Crue program
  - In delayed flights, revision of flight and crue programs

(flight alternatives, parameters, variables, objectives, constraints)

Complex Systems

- Mathematical field → Optimization

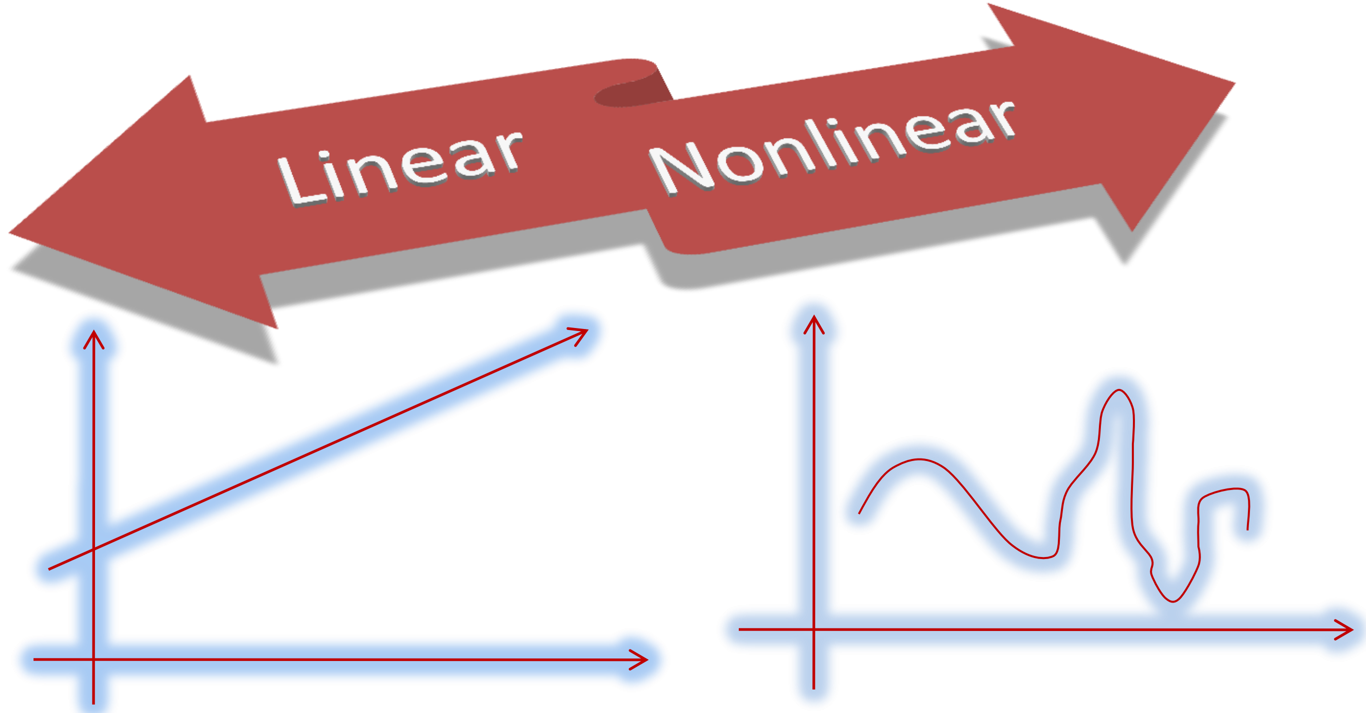
$$\text{Min } CX \quad \text{(cost) or Max } PX\text{(profit)}$$

$$AX=b \quad \text{(constraints)}$$

$$X\geq 0$$

Standard Linear Optimization Problem

Nonlinearity



Linear relations

- Linear relations
  - Q=-k(grad(Pressure)) (Darcy)
  - Q=-k(grad(Temperature))(Fourier)
  - Q=-k(grad(Concentration))(Fick)
  - F=-kx(Hooke)
  - I=1/RV(Ohm)
- Linear Model(ideal setting):

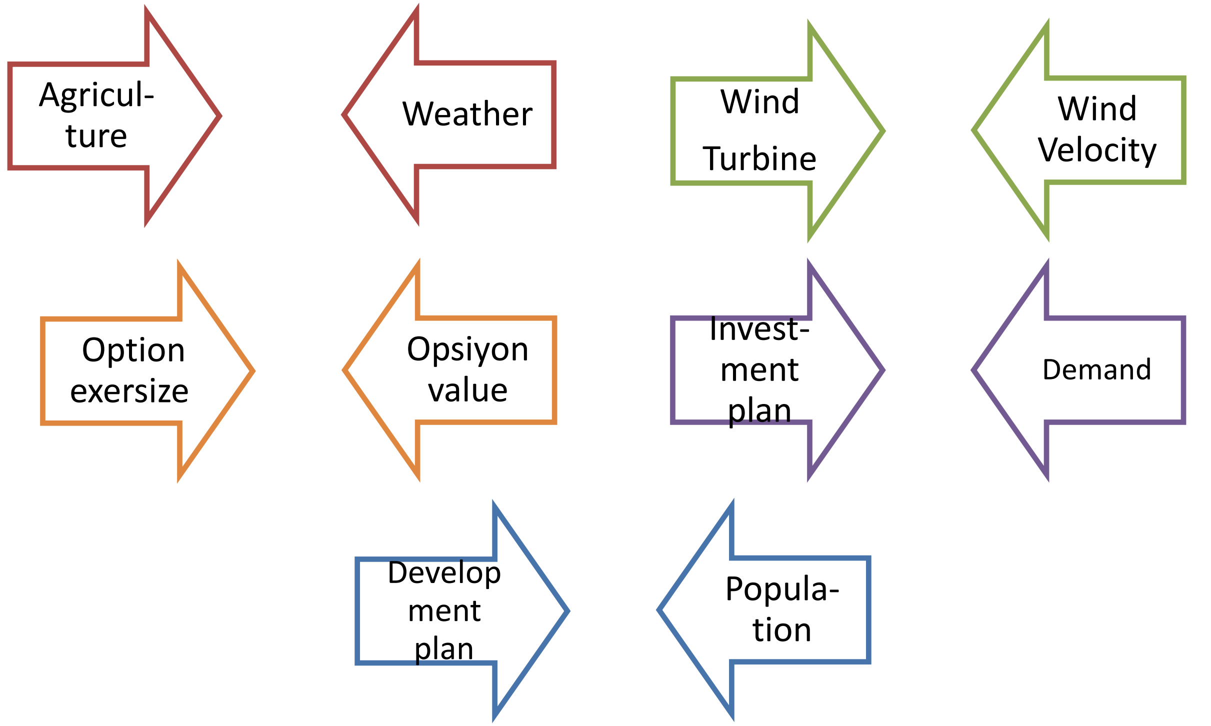
  Mathematical formulation of linear relations

Nonlinearity

- Nonlinear relations
  - Economy
    - Performance/salary
    - Profit/turnover, Inflation/budget deficit, Option price vs /Value of underlying asset
  - Science and engineering
    - Population vs time
    - Objects velocity vs resistance force
    - Temperature vs resistance to current
    - Viscosity vs temperature
  - Health sciences
    - Biochemical reactions
- Nonlinear Model

  Mathematical formulation of nonlinear relations

Desire to predict the future



Mathematical Model

Mathematical formulation that leads to a reasonable prediction

Other common features

- Uncertainity(consumer trends)
- Different time scales
- Large scale simulations(weather forcast, CAD)
- Security
- Dynamic resource allocation

Case Studies from Study Groups

Cuttings transport with drillstring rotation

Study Groups: European Study Group with Industry > ESGI 59 (Nottingham, UK, Mar 26-30, 2007)

Problem presented by

Paul Bolchover

Schlumberger

Problem statement

When an oil well is being drilled, rock cuttings are transported up to the surface by a flow of viscous non-Newtonian fluid. Current mathematical models of the flow and transport neglect the effects of drillstring rotation. Schlumberger wish to have a model that includes these effects. The Study Group identified many of the ingredients that need to go into building such a model.

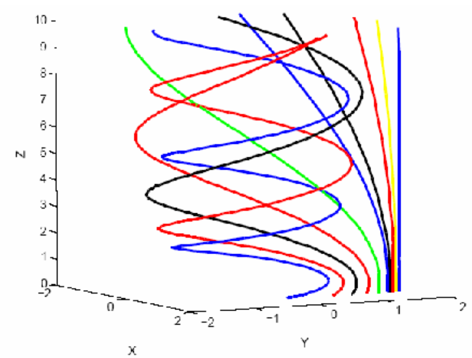


Figure 1: Particle Trajectories

1

Study Group contributors

David Allwright (Smith Institute)
Clare Bailey (Loughborough University)
Chris Cawthorn (DAMTP)
Andrew Cliffe (University of Nottingham)
Erhan Coskun (Trabzon)
Stephen Hibberd (University of Nottingham)
Gareth Jones (OCIAM)
John King (University of Nottingham)
Andrew Lacey (Heriot-Watt)
Rafael Morones (Mexico)
John Ockendon (OCIAM)
Giles Richardson (University of Nottingham)
Hannah Woollard (University of Nottingham)

Study Groups: European Study Group with Industry > ESGI 68 (Southampton, UK, Mar 30-Apr 3, 2009)

Chauffeur braking

Problem presented by

Phil Barber and Huw Williams

Jaguar Land Rover

Executive Summary

An experienced driver will 'feather' the brakes so as to unwind the suspension compliance and stop the vehicle with only just enough torque in the brakes to hold the vehicle stationary on any gradient, or against the residual torque from an automatic transmission's torque converter. An optimal stopping problem that minimises the total jerk was formulated and solved. This model was extended by including a linear relationship between the brake pressure and the acceleration of the car where the coefficients are estimated by linear regression. Finally, a Kalman filter estimates the state of the car using the tone wheel.

Study Groups: European Study Group with Industry > ESGI 68 (Southampton, UK, Mar 30-Apr 3, 2009)

(2.1.2) We define the *discomfort* J in terms of the velocity profile $v(t)$ over the stopping period $0 < t < T$ by

1

Chauffeur braking ESGI68

$$J[v,T] = \int_0^T (\ddot{v})^2 \, dt \,, \tag{1}$$

and assume that the smoothest ride is given by the trajectory $v(t)$ that minimises J. We wish to stop the car as smoothly as possible, bringing it to rest in a distance D from an initial velocity $v(0) = v_0$ and acceleration $\dot{v}(0) = a_0$. There are of course, other ways we could define the discomfort of a car coming to stop but the time intergral of the jerk squared is what we looked at during the week.

Study Groups(www.maths-in-industry.org)

2010

Apr 12–16	73rd ESGI, European Study Group with Industry University of Warwick (UK)
Apr 26–30	74th ESGI, European Study Group with Industry University of Aveiro (Portugal)
Jun 14–18	26th MPI, Workshop on Mathematical Problems in Industry Rensselaer Polytechnic Institute (USA)
Jun-Jul 27—2	75th ESGI, European Study Group with Industry University of Limerick (Ireland)
Jul 6–8	Study Group with the Steel Industry Annaba (Algeria)
Jul 26–30	Claremont Colleges Math-in-Industry Workshop Claremont (USA)
Aug 16–20	FMIPW 2010, Fields-MITACS Industrial Problem-Solving Workshop Fields Institute, Toronto (Canada)
Aug 25–29	76th ESGI, European Study Group with Industry Technical University of Denmark (DTU), Denmark (Denmark)
Sep 6–10	MMSG 2010, Mathematics in Medicine Study Group University of Strathclyde (Scotland, UK)
Sep-Oct 27—1	77th ESGI, European Study Group with Industry Stefan Banach International Mathematical Center, Warsaw (Poland)
Oct 4–8	1st Euro-Asian Study Group with Industry Karadeniz Technical University, Trabzon (Turkey)

Karadeniz Teknik Üniversitesi Türkçe / English

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- KAYIT
- PROBLEMLER
- PROGRAM
- PROBLEM ÖNER
- İLETİŞİM

EM2010'a Davet

Uluslararası Katılımlı Endüstride Matematik Çalıştayı, 04 - 08 Ekim, 2010 Trabzon, Türkiye

Avrupa'da 1960'lı yıllarda ilk olarak Oxford Üniversitesi'nde bir grup Uygulamalı Matematikçi ve Üretim Firması arasında başlatılan işbirliği kısa zamanda verimliliğini ispatlamış gözükmektedir. Günümüzde her yıl en az on farklı üniversitede Endüstriyel problemlerin matematiksel yöntemlerle çözümünü esas alan ve "Study group with Industry" isimli çalıştaylar düzenlenmektedir. Bu çalıştaylara ait bilgiler http://www.maths-in-industry.org adresinde yer almaktadır.. **Devamını Oku**

What Remains after ESGI73?(European Study Group with Industry, 12- 16 April, 2010, Warwick University, UK)

Another study group is left behind with memories that will last forever. We all have learned many things from this study group as well: Now, we know that math gets more involved with the nature around us and the search for new technology to make our lives better. This may involve the search for the reasons behind the failure of wind tribune, or degradation of agrochemicals on farm lands, or periodicity, if any, of hurricane paths, or diagnosis of received signals to see where they came from and what platforms they came from, or last but not least, even the search for a chair that is right for all! **Continue to Read**

2010 Yılı için Planlanan Endüstriyel Matematik Çalıştayları (IM Bulletin, January 2010)

DUYURULAR

Kayıt yaptıran katılımcıların dikkatine!

Lütfen kaydınızı 15 Eylül 2010 tarihine kadar matendustri@ktu.edu.tr adresine mesaj

KONAKLAMA ve ULAŞIM

- Haritalar
- Ulaşım
- Konaklama

ÖNCEKİ ENDÜSTRİYEL MATEMATİK ÇALIŞTAYLARI

- 1 nci Çalıştay
  25-27 Mayıs 2006

KTU Study Group, 2010

A

Acosta, Gabriel and Garcia, Patricia and Gonzalez, Juan D. and Estéfano, R. Alexis Muñoz (2010) Optimización del Tratamiento Térmico de Productos Tubulares de Acero. [Study Group Report]

Akin, O. and Khaniyev, T. and Kaya, I. and Kesemen, O. (2010) Adaptive Light Control System. [Study Group Report]

Alfie, Ezequiel and Guozden, Tomas and Maestri, Mauricio and Martnez, Julian and Sosa, Sebastian and Ziella, Daniel (2010) Monitoreo Inteligente de Procesos. [Study Group Report]

Arab, N and Bazarganzadeh, Reza and Ceseri, M and Gallimore, Laura and Lacey, Andrew and Lustri, Chris and Majdodin, Rooholah and Ockendon, John and Please, Colin and Seguis, Jean-Charles and Shabala, Alex and Smith, Amy and Smith, Nadia and Somfai, E and Whittaker, Robert (2010) Transport and Reaction Processes in Soil. [Study Group Report]

B

Brussee, R and Darau, M and Dworczynska, M (2010) Position Estimating in Peer-to-Peer Networks. [Study Group Report]

C

Chen, W. and Cor, B. and Konuralp, A. and Reis, T. and Sengul, S. (2010) Spinning Soccer Ball Trajectory. [Study Group Report]

Coskun, E. (2010) A Medical Waste Sterilizer. [Study Group Report]

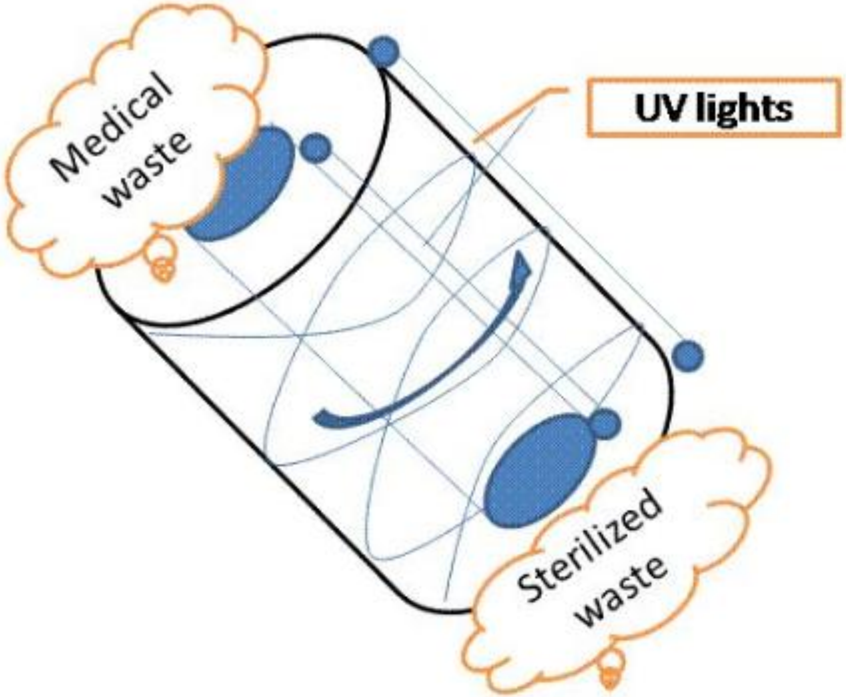
Cumberbatch, E. and Konuralp, A. and Koksoy, O. (2010) Handgun Accuracy Problem. [Study Group Report]

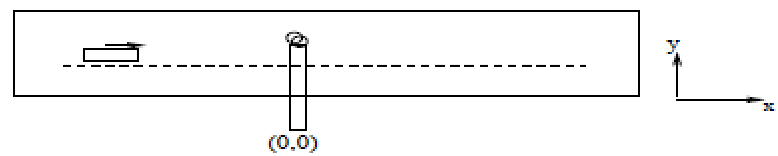
Medical waste sterilization device

with Germicidal UV lamps

Problem Presenter:

S. Hacısalihoğlu, TTSO, KTU Study Group, 2010





A single UV on a straight path

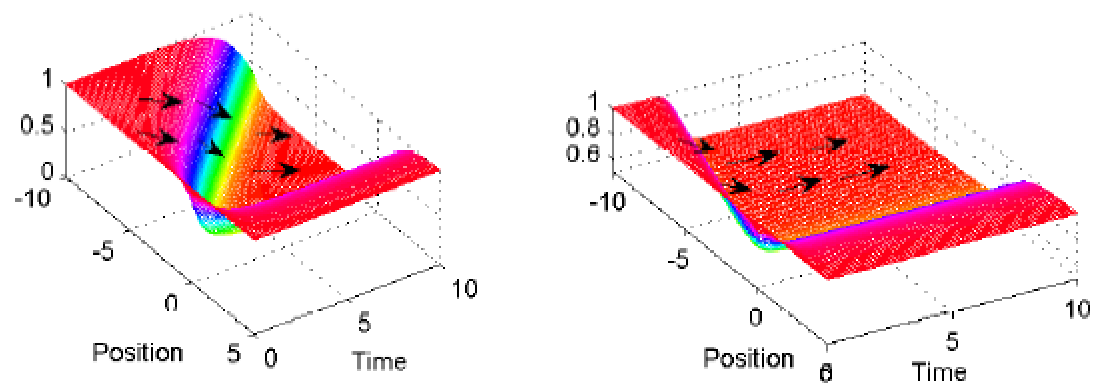


Figure 1: Depletion over characteristics for a range of initial positions with $u_0 = 1$(left) and $u_0 = 2$(right).The z axis represents medical concentration values c(x,t;y) along the trajectories $\xi = x - u_0 t = const$, denoted by arrows.

Followup work (E. Coskun)

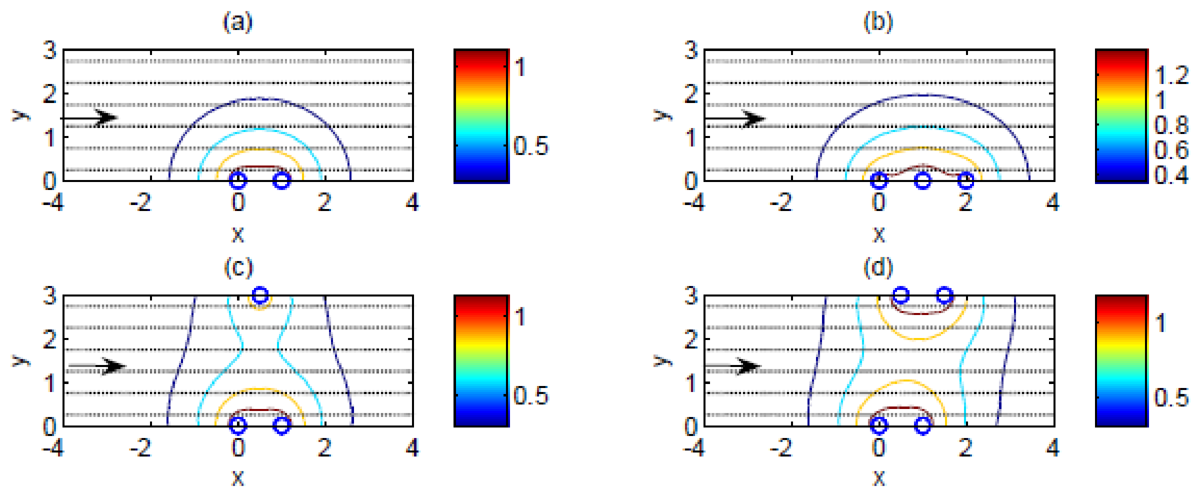


Figure 2: UV lights of various number and location sheding light on waste sample trajectories(y=const). $(x, y) = (0,0), (1,0)$(Figure2(a));$(x, y) = (0,0), (1,0), (2,0)$(Figure2(b)), $(x, y) = (0,0), (1,0), (1/2,3)$,(Figure2(c)) and $(x, y) = (0,0), (1,0), (1/2,3), (3/2,3)$(Figure(2(d)).

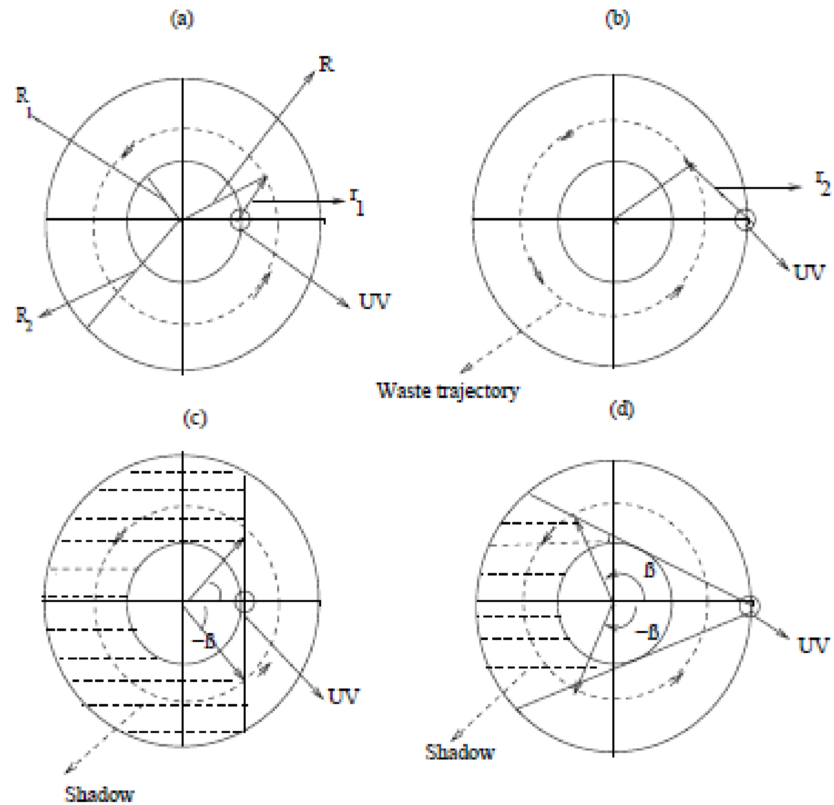
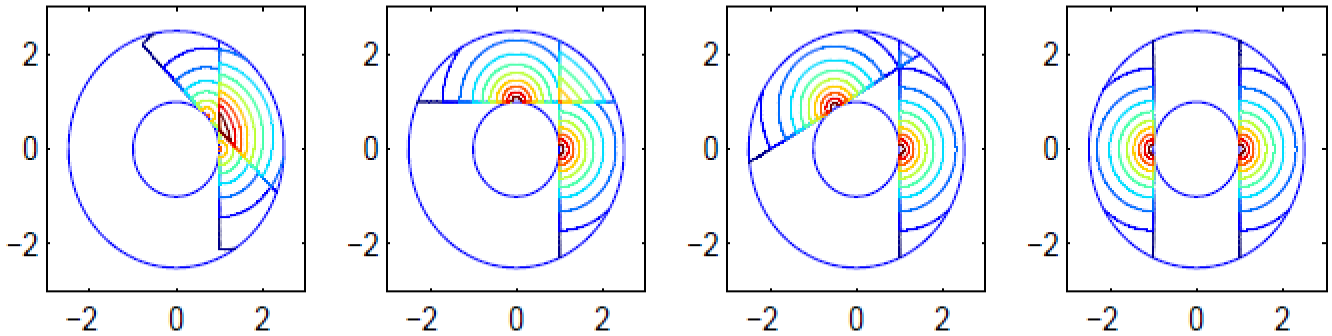


Figure 4: Crossection of medical sterilizer with particle trailing radius and UV lights



Two UV lamps along the inner cylinder as one changes position

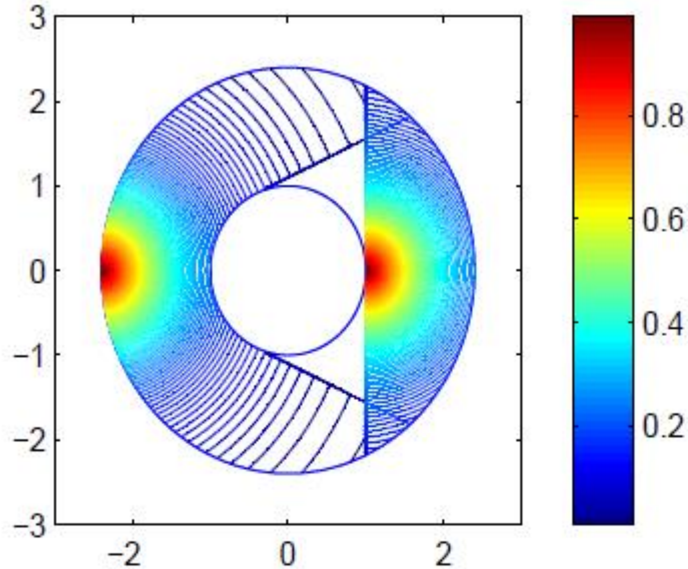


Figure 12: A UV_{in} at $(R_1, 0)$ and a UV_{out} at (R_2, π).

$$\begin{aligned} \frac{\partial c(\theta,t;R)}{\partial t} + v\frac{1}{R}\frac{\partial c(\theta,t;R)}{\partial \theta} &= -Q(r)c(\theta,t;R), t>0 \\ c(\theta,0;R) &= 1. \end{aligned}$$

Depletion of medical waste wrt position of second UV

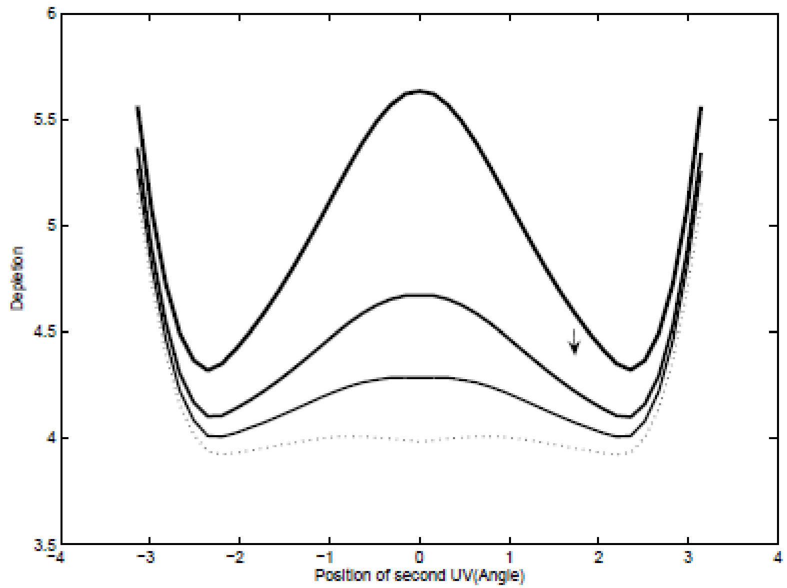


Figure 11: Position vs depletion for various w's

Spinning Soccer Ball Trajectory

Problem Presenters

Erhan Coskun[1]

Department of Mathematics, Karadeniz Technical University,

Trabzon, Turkey

Problem Statement

As can be remembered from the recent World Cup, uncertainities in the trajectory of a soccer ball at high speeds have led to some criticism on the ball manufacturers. The existing ball trajectory models assume that as the ball spins, a layer of air, say a boundary layer, follows the motion of the ball, thus spins with it. This, in turn, induces a velocity difference on the sides normal to ball's trajectory. The velocity difference then leads to pressure difference due to Bernoulli's principle. If represents the axis of spin and is the linear velocity, the resulting Magnus force would be in the direction of .

Figure. A soccer ball trajectory and the induced velocity difference

Initialization Strategy for Nonlinear Systems

Coskun, E. (2011) *Initialization Strategy for Nonlinear Systems*. [Study Group Report]

PDF
477Kb

Abstract

The Study Group was asked to provide some hints concerning a choice of initial values to be used for nonlinear algebraic systems. The group has considered the available options and outlined the pros and cons of various methods and provided some recommendations.

Item Type:	Study Group Report
Problem Sectors:	Energy and utilities None/Other
Study Groups:	KAUST Study Groups > 1st KSG (Thuwal, Saudi Arabia, Jan 23-26, 2011)
Company Name:	Saudi Basic Industries Corporation (SABIC)
ID Code:	347

Given a nonlinear algebraic system

$$F(X) = 0 \tag{1}$$

where

$$F \colon \mathbb{R}^n \to \mathbb{R}^n$$

is a smooth function in the sense that it will justify the requirements for a chosen numerical method, the question presented to the Study Group was how to choose an initial guess $X^{(0)} \in \mathbb{R}^n$ to solve the system 1 provided that such a solution $P \in \mathbb{R}^n, F(P) = 0$, does exist.

1 Catalytic Liquid Phase Reaction Model

A mass-tranfer limited heterogeneous catalytic liquid phase reaction model is presented in ([1]) to test the performance of software packages to solve similar problems. In a reactor, component A reacts with B to form C and components C reacts with A to form D. All the reactions are taking place in the liquid phase at the outer surface of spherical catalyst particles.

The reactor contains liquid and spherical catalyts. The catalysts are assumed to of the same size. The model for a tubular reactor of length L reads

$$
\begin{aligned}
\frac{d[B]}{dx} &= -\alpha([B]-[B]_s) \qquad (1)\\
\frac{d[C]}{dx} &= \beta(R_1-R_2)\\
\gamma([A]-[A_s]) &= (R_1+R_2)\\
\frac{\alpha}{\beta}([B]-[B]_s) &= R_1
\end{aligned}
$$

where

$$
\begin{aligned}
R_1 &= \frac{k_1K_{1m}K_{2m}[A]_s[B]_s}{\left(1+\sqrt{K_{1m}[A]_s}+K_{2m}[B]_s+K_{3m}[C]\right)^3}, \qquad (2)\\
R_2 &= \frac{k_2K_{1m}K_{3m}[A]_s[C]}{\left(1+\sqrt{K_{1m}[A]_s}+K_{2m}[B]_s+K_{3m}[C]\right)^3}
\end{aligned}
$$

and $x \in [0,L]$ is the spatial variable along the reactor, $\alpha = 1442, \beta = 28.8, \gamma = 9.88$.

The system is to be solved over $(0, L]$ with given constant concentration A,and the feed concentrations $[B]_0, [C]_0$. We investigate the following problems associated with the system (1):

- **Forward problem**: Starting with initial values $[B]_0, [C]_0$ with appropriate set of kinetic parameters $k_1, k_2, K_{1m}, K_{2m}, K_{3m}$ determine the exit values $[B]_L, [C]_L$.
- **Parameter estimation problem**: Starting with intial values $[B]_0, [C]_0$, and the constant concentration A, determine the parameters k_1, k_2, K_{1m}, K_{2m}, K_{3m} that gives the experimental exit values $[B]_L, [C]_L$ provided in the Table below from Eurokine experiments

Table 1: Eurokine experimental test results([1])

Exp.	Reactor L.	$[A]$	$[B]_0$	$[C]_0$	$[D]_0$	$[B]_L$	$[C]_L$	$[D]_L$
1	0.165	2.67	25.39	3918	610.8	3.73	3914.1	636.3
2	0.165	2.67	50.78	3893	610.8	40.0	3901.6	613.0
3	0.165	2.67	76.17	3868	610.8	67.8	3875.7	611.5
4	0.232	2.67	25.39	3918	610.8	0.392	3904.3	649.5
5	0.232	2.67	50.78	3893	610.8	36.0	3901.1	617.4
6	0.232	2.67	76.17	3868	610.8	60.6	3881.6	612.7
7	0.165	10.68	25.39	3918	610.8	0.006	3849.6	704.5
8	0.165	10.68	50.78	3893	610.8	4.34	3923.0	627.2
9	0.165	10.68	76.17	3868	610.8	53.0	3888.8	613.1
10	0.232	10.68	25.39	3918	610.8	0	3796.3	757.9
11	0.232	10.68	50.78	3893	610.8	0.094	3870.0	684.4
12	0.232	10.68	76.17	3868	610.8	34.2	3903.0	617.7

1.2 Exit Concentrations with estimated Parameters

Test 1 L=0.165, [A]=2.67

$[B]_0 = 25.39$	$[C]_0 = 3918$	B=3.730000078017
k1=298.193343127627	k2=199.436619426085	C=3914.100000151133
k1m=3.092562255246	k2m=0.013276044278	k3m=0.000066956221

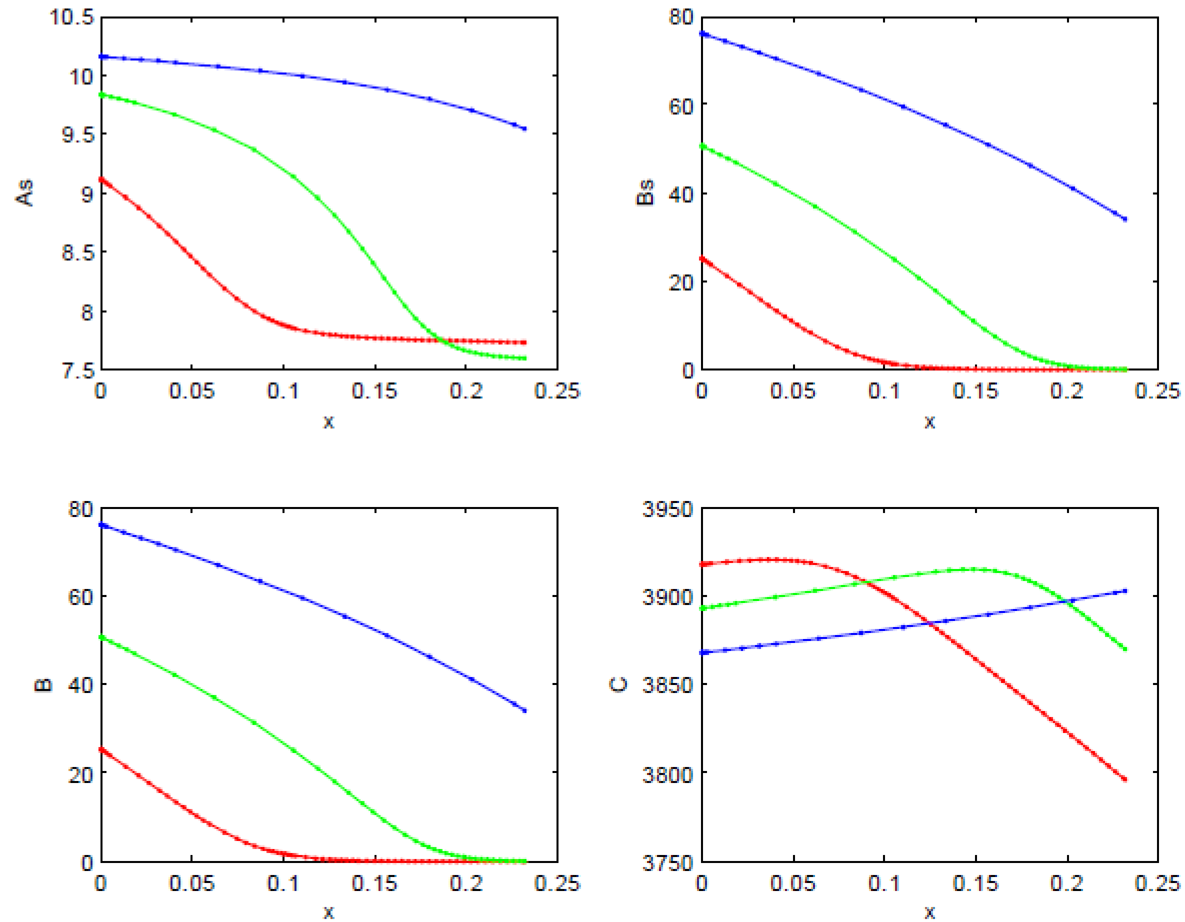
Eurokin Measurement [B]=3.73, [C]=3914.1

Test 2: L=0.165,[A]=2.67

$[B]_0 = 50.78$	$[C]_0 = 3893$	B=40.000251608034
k1=300.905698103240	k2=204.437579429260	C= 3901.600556494715
k1m=2.815280014027	k2m=0.350900834990	k3m=0.001208801172

The parameters are in the suggested ranges, yet we were unable to obtain them correctly by the end of the Study Group. The parameters for the experiments are obtained by a search algorithm using a Nonlinear Least Squares Method with lsqnonlin of MATLAB.

For the Test 10,11, and 12, in the following figure we display the variation of the solution components along the reactor with the estimated parameters.



Solution components along the reactor. Red(Test 10), Green(Test 11), Blue(Test 12)

Follow up work of KAUST SG, Parameter sensitivity analysis and regularization, E. Coskun

Case Studies from a Recent Study Group

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

1. Inertial Navigation for Divers

A Scuba diver would like to know his/her position underwater, relative to the dive start position. A mathematical theory for a dead-reckoning system is needed.

Nick Bushell, VR Technology.

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

2. A Model for the Reduction of Specific Surface Area of Powders with Age

Interested in explosives in the form of powder. High surface area, small diameter powders have high Gibbs energy and tend to coarsen to reduce it. Mathematical model of coarsining under heating is needed (A generalization of Ostwald-Ripening model)

John Curtis, Rod Drake & Janella Mansell, AWE

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

$$E_\epsilon(c) = \int_\Omega \left(f(c(x,t)) + \frac{\epsilon}{2} |\nabla c(x,t)|^2 \right) dx$$

$$u = c_{xx},$$

$$c_t = (f'(c) - \epsilon u_{xx})_{xx},$$

$$c_x(\pm 4,t) = u_x(\pm 4,t) = 0, t > 0$$

$$c(x,0) = c_0(x).$$

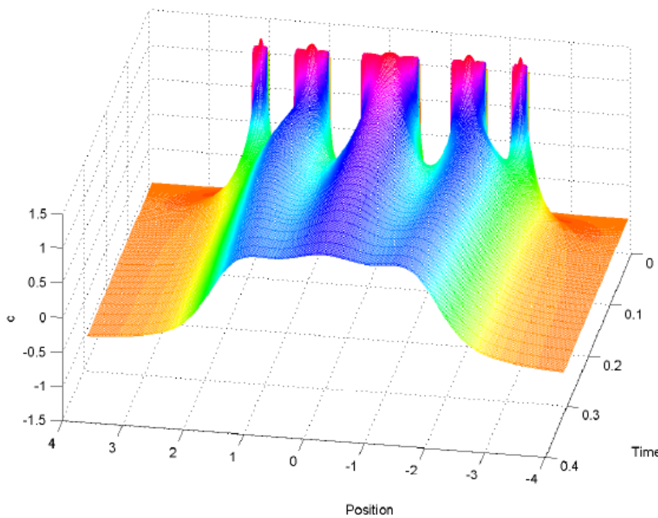


Figure 2: Ripening in a binary system with five particles of varying sizes.

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

3. Probabilistic Flood Forecasting

Using the data on river levels and weather forcasts of the past, determine a flood forcast model using a recent weather forcast data.

Mike Vaughan,

UK Environment Agency

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

4. Determining 3D Body Shape from 2D Images

Using two digital photographs of a person, compute the person's 3D shape

David Evans & Eleanor Watson,

Poikos Ltd.

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

5. Efficient Geometrical Description of Perturbations to Designed Shape

Consider an artefact such as an aircraft component, say wing. Accuracy of the artefact can be verified if it is measured. Having measurements of the form (x,y,z), determine a mathematical procedure that will describe the perturbations from nominal shape.

Amir Kayani & Richard Burguete

Airbus Operations Ltd.

Recent Study Group Problems

85th European Study Group with Industry

16th–20th April 2012, University of East Anglia, Norwich

6. Liquid Interactions with Porous Media and the Environmental Fate of Toxic Materials

Consider a toxic liquid droplet, develop a model that will determine

- Droplet movement on the surface,
- Absorption into the material
- Evaporation from the surface and evaporation with the porous material
- airborne transfer away from the surface

Simon Parker & James Nally

Defence Science & Technology Laboratory

Fields of Priority for the next five years

[Maths in Industry report, European Science Foundation]

- ✓ Optimisation(discrete, continuous, constraints of any type: algebraic,ode,sde, and combinations)
- ✓ Control and dynamics of real processes
- ✓ Mathematical modelling(for complex industrial problems, in particular)
- ✓ Visualization (medicine and engineering)
- ✓ Data mining in science and engineering

SIAM 2012 report on maths in industry

– «Industrial mathematics is a specialty with a curious case of double invisibility.....
– ... We are convinced that the mathematical and computational sciences have contributed and will continue to contribute to the nation’s economy by providing new knowledge and new ways of doing business.
– Nonacademic applications enrich and deepen the mathematical and computational sciences as well as other fields, ...»

2013

Jan 14-18	Johannesburg (South Africa): University of the Witwatersrand **Mathematics in Industry Study Groups in South Africa, 10**
Jan (9-12)	**(Graduate workshop. Level: Masters, PhD)**
Jan 14-18	Palo Alto, California (USA): American Institute of Mathematics **Modeling Problems Related to our Environment**
Jan-Feb 28-1	Leiden (Netherlands) **90th European Study Group with Industry**
Jan-Feb 29-2	Brisbane (Australia): QUT **Australia and New Zealand Mathematics in Industry Study Groups, 2013**
Jan (22-26)	**(Graduate workshop. Level: Honours, PhD)**
Apr 15-19	Bristol (UK): University of Bristol **91st European Study Group with Industry**
Apr (9-12)	**(5th UK Graduate modelling camp, University of Oxford)**
May 6-10	Coimbra (Portugal): Instituto Superior de Engenharia de Coimbra **92nd European Study Group with Industry**
Jun 10-14	Istanbul (Turkey) **2nd Euro-Asian Study Group with Industry**

2nd Euroasian Study Group(?)

Study groups lead to

- New research problems and collaboration chances for academics,
- Opportunity for graduate students to have hands-on experience with real world problems in a free discussion environment,
- New insight for companies, much more than they can get from a single consultant,
- Motivation to study math or keep studying math for undergraduates,
- Disclosure of the role of mathematics in academic and non-academic environments.
- …

References

1. F. Avner, L. John How to start an Industrial Mathematics Program in the University, SIAM, Preprint.
2. Report on mathematics-in-industry(April 2009), Global Science Frorum,OECD, www.oecd.org/science/scienceandtechnologypolicy/42617645.pdf
3. EM2010(Uluslararası katılımlı Endüstriyel Matematik Çalıştayı, KTÜ, Trabzon), Çalıştayı(matendustri.ktu.du.tr)
4. ESGI85, 85th European Study group with industry, 12-16 Nisan 2012, University of East Anglia, UK.
5. Master of Science in Industrial Mathematics, Michigan State University, http://www.math.msu.edu/Academic_Programs/graduate/msim/.
6. Mathematics and Industry, ESF(www.esf.org)
7. SIAM 2012 report on maths in industry(www.siam.org)

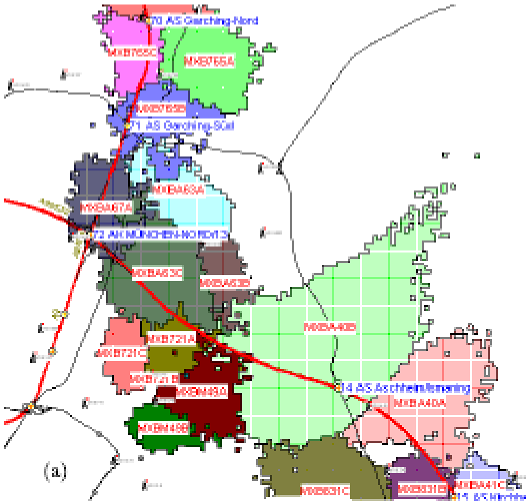
Case Studies from Previous Years

Economy

Estimation of sensitivity of oil prices

- Firm: EPRasheed
- The Firm wants to determine the fluctuations in oil prices under some assumptions
- ESGI 68., Southampton 2009, UK.

Traffic



Routing traffic with mobile phones

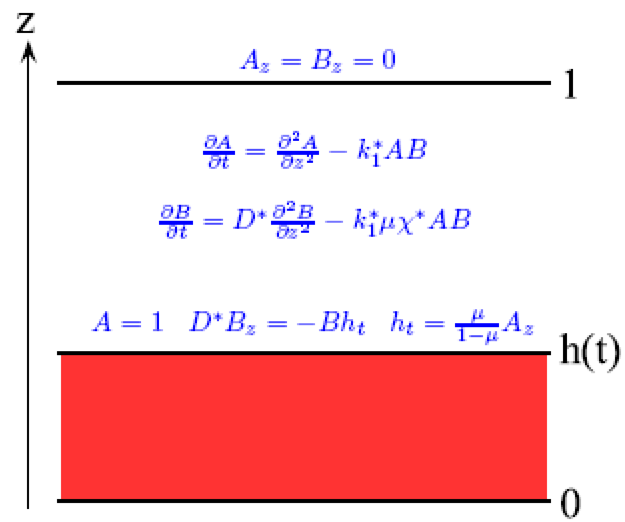
Firm: Vodafone

Wants to use the information in base stations to reroute traffic

ESGI 49, Oxford, 2005

Environment

- Firm: DSTL(UK)
- Cleaning capability of detergents on a substrate
- ESGI 68.
- Southampton,UK, 2009

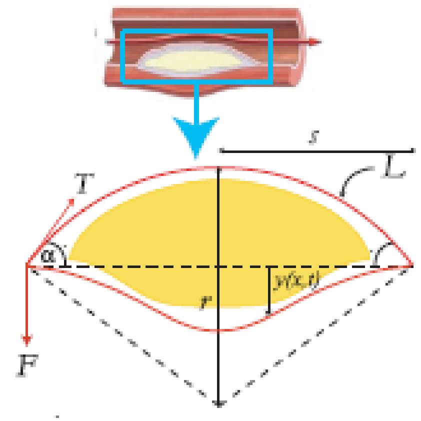


Medicine(Plaque)

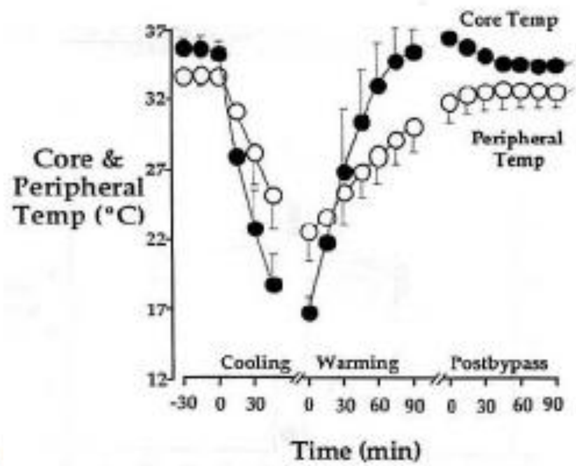
Firm: Christiana Care Health System

Firm wants to analyse plaque development and breakup mechanisms

Delaware Study Group, US, 2009



Medicine (cooling and rewarming during surgical operation of a heart)



ESGI 52, Amsterdam, 2005

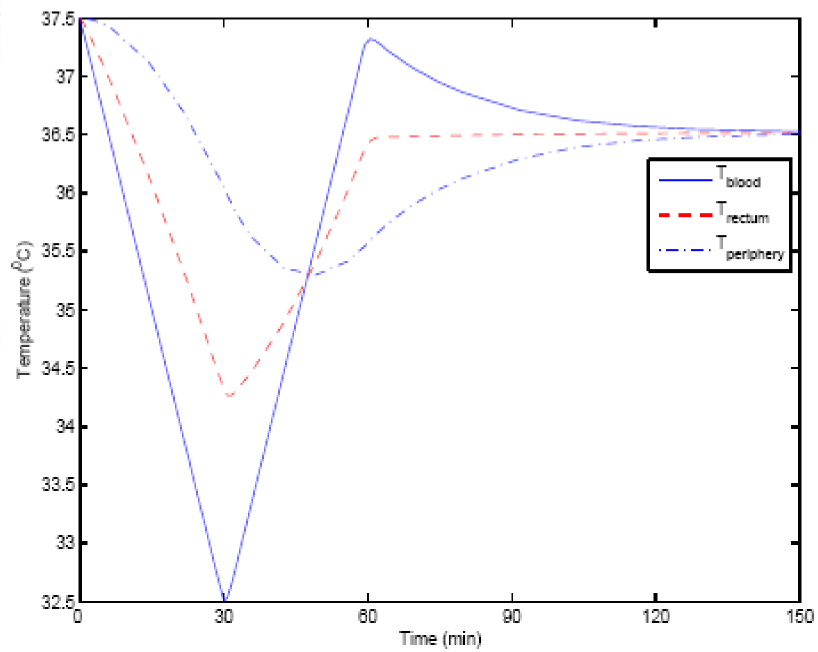


Figure 4: (a) The cooling and rewarming procedure for a surgical time of 60 minutes and (b) The effect of a short surgical time on the rewarming procedure. Note the small afterdrop in temperature.

Air transportation

- Firm KLM
  - Planning of drinking water in a plane
  - ESGI 52. Amsterdam, 2005
- Firm Airbus
  - Aircraft gas tank height-volume characteristics
  - ESGI 56. , Bath, 2006

Gas lines

- Firma Veeder-Root
- Wants to determine gas leaks in gas lines
- 21. MPI , Worcester, US, 2005

PV=NRT

Consumer trends

- Firm Unilever, UK
- Wants to determine consumer trends
- To consider
  - Psychological and
  - Sociological factors
  - ESGI 49, Oxford, 2005.

Thanks!