Mathematics for Industry 11

Robert S. Anderssen · Philip Broadbridge
Yasuhide Fukumoto · Kenji Kajiwara
Tsuyoshi Takagi · Evgeny Verbitskiy
Masato Wakayama *Editors*

Applications + Practical Conceptualization + Mathematics = fruitful Innovation

Proceedings of the Forum of Mathematics for Industry 2014

Springer

Mathematics for Industry

Volume 11

Aims & Scope

The meaning of “Mathematics for Industry” (sometimes abbreviated as MI or MfI) is different from that of “Mathematics in Industry” (or of “Industrial Mathematics”). The latter is restrictive: it tends to be identified with the actual mathematics that specifically arises in the daily management and operation of manufacturing. The former, however, denotes a new research field in mathematics that may serve as a foundation for creating future technologies. This concept was born from the integration and reorganization of pure and applied mathematics in the present day into a fluid and versatile form capable of stimulating awareness of the importance of mathematics in industry, as well as responding to the needs of industrial technologies. The history of this integration and reorganization indicates that this basic idea will someday find increasing utility. Mathematics can be a key technology in modern society.

The series aims to promote this trend by (1) providing comprehensive content on applications of mathematics, especially to industry technologies via various types of scientific research, (2) introducing basic, useful, necessary and crucial knowledge for several applications through concrete subjects, and (3) introducing new research results and developments for applications of mathematics in the real world. These points may provide the basis for opening a new mathematics-oriented technological world and even new research fields of mathematics.

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Preface

This book is the proceedings of the conference “Forum Math-for-Industry 2014,” for which the unifying theme was “Applications + Practical Conceptualization + Mathematics = fruitful Innovation.” This epigram encapsulates the dynamics of the process that takes an application through to an innovation. Industrial mathematics can be viewed as the causal engine that implements the epigram by taking an Application such as input and convolving it with a mixture of Practical Conceptualization and Mathematics to generate a fruitful Innovation as output.

In industrial mathematics, the questions spawned by real-world applications are what drive the resulting two-way interaction between a particular application and the associated mathematics that is utilized and developed, and that sometimes involves, quite unexpectedly, deeper aspects and new areas of mathematics than initially anticipated.

The plan for the talks at the forum was to illustrate various aspects of this two-way interaction between applications and the associated highlighting of how the practical conceptualization assists with the linking of the question that encapsulates the current application to the relevant mathematics. The organizers believe the plan was quite successful. Readers will find in this proceedings that the forum can actually be viewed as a way for unifying the two-way interaction between applications and mathematics.

In a mathematics-for-industry situation, although the application context and the desired innovation are notionally relatively clear, it takes time to identify the questions to be resolved. It is at this stage that conceptualization plays a key role through the generation of a plethora of possibilities of how to link various questions to the mathematics that will generate reliable and useful answers. In a way, one is reminded of this quotation from Edward David: “The importance of mathematics is not self-evident.”

It acknowledges the fact that the role of mathematics plays in solving real-world problems is often taken for granted. Circumspectly, using mathematics to solve real-world problems is similar to a sculptor working with mechanical devices to chisel out one of the possible forms hidden in the block of wood or stone being carved. The one chosen is the result of the current subconscious conceptualization of the artist. That sculpturing could be viewed from this perspective can be found in Soseki Natsume's series of short stories "Ten Nights of Dreams" (*Yume-Juya*) in the Meiji Period (1868–1912). On the sixth night, the dreamer subconsciously visualizes Unkei, the famous Japanese twelfth-century sculptor (1150–1223), in the act of carving the two forbidding guardians of the Buddha Nio guarding the main gate of the Gokoku-ji Temple. Unkei is so absorbed in the carving, he is unaware of the noisy crowd gathered around him. The dreamer then visualizes that some onlookers theorize that the sculpture of the guardians is already hidden in the wood which Unkei is discovering rather than creating. The dreamer then concludes that he should also be able to find Nio in the wood and heads home to attempt it. Unfortunately, he is not able to find one. The dreamer thereby concludes that Nio is no longer in the wood of the Meiji Period.

The first Japanese Field Medallist Kunihiko Kodaira, in 1954, echoed this analogy in his remark that his theory of elliptic surfaces was not invented by him but was just sculptured, using paper and pencil, from the wood of mathematics where it was waiting to be discovered. The corresponding analogy for industrial mathematics, independent of the dynamics outside the context of the application being examined, is: "Answers to the questions that arise in an application are sculptured into reality using the tools of mathematics, which are thereby developed and sharpened by this process."

We would like to thank the participants of the forum, especially the members of the Scientific Board of the Forum. Without their cooperation and support, we would never have experienced the great excitement and success of the forum. Moreover, we would like to express our deep appreciation for the great help of the conference secretaries, especially Tsubura Imabayashi during the preparation and organization of the forum, and Chiemi Furutani for the proceedings.

Fukuoka, Japan
April 2015

Masato Wakayama
On behalf of the Organizing Committee
of the Forum Math-for-Industry 2014
and the Editorial Committee of the Proceedings

FMI2009	FMI2009	FMI2010	FMI2011	FMI2012	FMI2013	FMfI2014
Tokyo	Fukuoka	Fukuoka	Honolulu	Fukuoka	Fukuoka	Fukuoka
Sep. 19-17	Nov. 9-13	Oct. 21-23	Oct. 24-28	Oct. 22-26	Nov. 4-8	Dec.27-31
The 1st Forum:Consortium Math For Industry	Casimir Force, Casimir Operators and the Riemann Hypothesis	Information Security, Visualization, and Inverse Problems, on the basis of Optimization Techniques	TSUNAMI - Mathematical Modelling- Using Mathematics for Natural Disaster Prediction, Recovery and Provision for the Future -	Information Recovery and Discovery	-The Impact of Applications on Mathematics-	-Applications + Practical Conceptualization + Mathematics = fruitful Innovation-


Forum "Math-for-Industry" 2014
Applications + Practical Conceptualization + Mathematics = fruitful Innovation
October 27(Mon) - 31(Fri), 2014
Venue: Nishijin Plaza, Kyushu University
2-16-23 Nishijin, Fukuoka City
Invited Speakers
Gary Froyland University of New South Wales
Masahito Hasegawa RIMS, Kyoto University
Hans-Christian Hege Zuse-Institute Berlin (ZIB)
Thorsten Koch TU Berlin / Zuse-Institute Berlin (ZIB)
Kerry Landman The University of Melbourne
Vladimir Lorman CNRS & Université Montpellier 2
Reinout Quispel La Trobe University
Ernesto G. Birgin University of São Paulo
Daniel Braak University of Augsburg
Íñigo L. Egusquiza University of the Basque Country, Bilbao
Farid Melgani University of Trento
Robert Norman RMIT University
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Enrique Solano University of the Basque Country, Bilbao
Akira Takada Asahi Glass Co., Ltd.
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Troy Farrell Queensland University of Technology
Luke Fullard Massey University
Arnab Ganguly University of Louisville
Sachiko Ishida Meiji University
Shinsaku Kiyomoto KDDI R&D Laboratories, Inc.
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Forum "Math-for-Industry" 2014

-Applications + Practical Conceptualization + Mathematics = fruitful Innovation-

October 27 to 31, 2014, Nishijin Plaza, Fukuoka, Japan

	October 27, 2014		October 28, 2014		October 29, 2014		October 30, 2014		October 31, 2014
	Registration		Registration		Registration		Registration		Registration
9:50	Opening Ceremony								
10:00 - 10:50	Thorsten Koch TU Berlin / Zuse-Institute Berlin (ZIB) Mixed-Integer Nonlinear Programs for Gas Network Optimization	9:45 - 10:35	Kerry Landman University of Melbourne An Interaction with Biologists: Insights into Development and Disease	9:45 - 10:35	Gary Froyland University of New South Wales Dynamical Systems Approaches to Analysing Transport in Geophysical Fluid Flow	9:45 - 10:35	Hans-Christian Hege Zuse-Institute Berlin (ZIB) Visual Analysis of Molecular Dynamics Data Using Geometric and Topological Methods	9:45 - 10:35	Masahito Hasegawa RIMS, Kyoto University Programming Languages, Tensor Categories, and Quantum Topology
10:55 - 11:30	Kenichi Arai NTT Communication Science Laboratories Synchronization of Semiconductor Lasers for Secret Key Distribution	10:40 - 11:15	Arnab Ganguly University of Louisville Modeling Biochemical Reaction Systems with Markov Chains	10:40 - 11:15	Akira Takada Asahi Glass Co., Ltd. Mathematical Modeling of Inorganic Glass Materials	10:40 - 11:15	Shinsaku Kiyomoto KDDI R&D Laboratories Inc. Towards Privacy-Preserving Services, -Risk Analysis and Solution-	10:40 - 11:15	Takashi Sasaki Yokogawa Electric Corporation Modeling and Control in Paper-Making Machines
11:35 - 12:10	Zainal Abdul Aziz Universiti Teknologi Malaysia UTM-CIAM: Transformation and Beyond Malaysian Mathematics for Industry	11:20 - 12:05	Daniel Braak University of Augsburg Analytical Solutions of Basic Models in Quantum Optics	11:20 - 12:05	Akira Ohata Toyota Motor Corporation Boundary Model Identification for Automotive Engine Controls	11:20 - 12:05	Robert Norman RMIT University Platform Technologies for Space Atmosphere and Climate: An Australian Space Research Program Project	11:20 - 12:05	Farid Melgani University of Trento Recent Methods for Reconstructing Missing Data in Multispectral Satellite Imagery
	LUNCH		LUNCH		LUNCH		LUNCH		LUNCH
13:40 - 14:30	Vladimir Lorman CNRS & Université Montpellier 2 Group Theory Methods in Virology: Landau Density Wave Approach	13:35 - 14:20	Enrique Solano University of the Basque Country, Bilbao Quantum Simulations and Quantum Technologies	13:35 - 14:25	Reinout Quispel La Trobe University Geometric Numerical Integration of Differential Equations and its Applications	13:35 - 14:10	Luke Fullard Massey University Modelling the Discharge of Particulates from a Hopper-Silo System– How a 6 week Industrial Contract Turned into a Research Career	13:35 - 14:10	Roger C. E. Tan National University of Singapore Sensitivity Analysis and its Numerical Methods for Quadratic Eigenvalue Problems
14:35 - 15:20	Ernesto G. Birgin University of São Paulo Applications of Nonlinear Programming to Packing Problems	14:25 - 15:35	Young Reseacher Session Alexandra Hogan A Model for Respiratory Syncytial Virus (RSV) Transmission Keita Iida Research to Construct a Mathematical Theory that can Compute Stochastic Cellular Processes Yasuaki Kobayashi Mathematical Modeling for Epidermal Structure	14:30 - 15:05	Íñigo L. Egusquiza University of the Basque Country, Bilbao Beyond Adiabatic: Effective Hamiltonians and Singular Perturbation	14:15 - 15:25	Young Reseacher Session Lucas Lamata Quantum Simulations with Trapped Ions and Superconducting Circuits Mikel Sanz Quantum Biomimetics and Bio-Inspired Quantum Devices Eriko Shinkawa Uniqueness and Stability for Double Crystals in the Plane	14:15 - 14:50	Toshinao Yoshiba Bank of Japan Risk Aggregation with Copula for Banking Industry
	COFFEE BREAK		COFFEE BREAK		COFFEE BREAK		COFFEE BREAK		COFFEE BREAK
15:40 - 16:15	Sachiko Ishida Meiji University Origami Evolution from Mathematics to Engineering	15:55 - 18:00	Poster Session	15:30 - 16:00	APCMfI Launch Ceremony -"The Importance and Future of APCMfI"-	15:45 - 18:00	Poster Session Award Ceremony	15:10 - 15:55	Konrad Polthier Freie Universität Berlin Reliable Computing in Geometry Processing and CAGD
16:20 - 16:55	Troy Farrell Queensland University of Technology Mathematics for Industry: A Mining and Resources Case Study			16:05 - 17:00	Poster Session Voting			16:00	Closing
	Welcome Party (Snack & Beverages)		PHOTO	18:00	Banquet Hilton Fukuoka Sea Hawk		PHOTO		Excursion

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Contents

UTM-CIAM: Transformation and Beyond Malaysian Mathematics for Industry

Zainal Abdul Aziz and Arifah Bahar

Abstract This article deliberates on how the Malaysian industries and mathematicians have come to revive the synergy of mathematics and industry through the Malaysian Mathematics in Industry Study Groups (MISG 2011, 2014). The Malaysian setting of pre MISG was a disengaged connection between industries and mathematics. Post MISG 2011 and 2014 have seen intensified partnership between local industries and mathematical community beginning to crystallize. The founding of UTM Centre for Industrial and Applied Mathematics (UTM-CIAM) with seven permanent staff at the end 2012 was a follow-up effect of the MISG 2011. It is a positive transformation for the Malaysian Mathematics for Industry scene. The Malaysian MISG is organized in cooperation with Oxford Centre for Industrial and Applied Mathematics (OCIAM), University of Oxford. These are collaborative problem-solving workshops where more than seventy mathematicians, operational researchers and statisticians deal with real life problems brought up by six private and public companies. These workshops assist to find out promptly the key scientific issues and mathematical challenges to be confronted. The meeting provides opportunities for bridging the gap between academics and scientists from Malaysian industry, and encourages innovative knowledge and technology transfer. This work also summarizes the successful collaboration formed between academics and industry practitioners in solving specific problems from the national high revenue industries during the Malaysian MISG 2011 and 2014.

Keywords Industrial mathematics · UTM-CIAM · MISG · OCIAM · Malaysian industry · STEM · Mathematical modelling

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1 Introduction

Scientific research methods and outcomes are essential to the progress of industrial innovation. These related researches are strengthened and driven basically by industrial mathematics. However, due to the nature of mathematics as an enabling technology for the innovative industry, its input is rarely visible in the final product that industry delivers. Current manufacturing and technology, engineering and service industries have progressed dramatically in modern times due to the upsurge in the knowledge-based economy. Speedy and inexpensive computing, the growth and exploitation of huge databases to cope with this sudden requirement, certainly have necessitated advanced methods to meet new demands. Industrial mathematics is principally one of the enabling factors in carrying out and implementing these methods. One of the important fundamental factors in this respect is the use of theoretical mathematics as the primary driving feature for innovation. Only through mathematics can the complex processes and products in current major technologies and innovation cycles be administered in a cost-effective, strong and sustainable way. In this new millennium, realistically it is most useful to assume a thorough outlook of industrial mathematics research. In particular, this can be based primarily on the precise idea of "construction and analysis of models", as portrayed in Fig. 1, [1, 2]. This treatment becomes more effective if the underlying fundamental knowledge is based on theoretical mathematics and the closely related fields as in STEM (Science, Technology, Engineering and Mathematics). This work demonstrates that industrial mathematics will be a major enabling technology for the Malaysian industries.

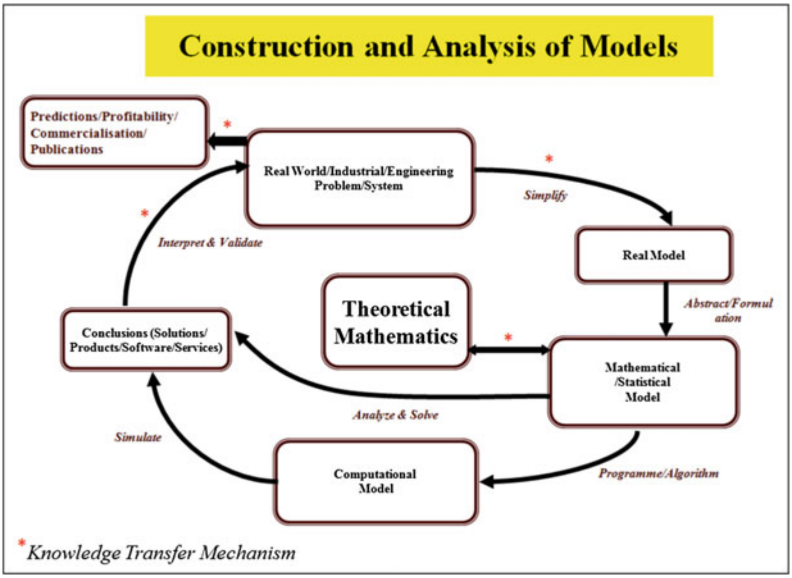

Fig. 1 Construction and analysis of models

This work elucidates on how the Malaysian industries have come to stimulate the synergy of mathematics and industry through the Malaysian Mathematics in Industry Study Groups (MISG 2011 and MISG 2014). The Malaysian setting before MISG experienced a disengaged relation between industries and mathematics. There was no earnest relationship for the local industries to provide industrial problems and equally no takers from the Malaysian mathematical community to offer decision support and solutions. Post MISG 2011 and 2014 have seen intensified partnership between local industries and mathematical community beginning to crystallize. Letters of Intention which lead to Memorandums of Understanding were signed and further collaborative problem solving efforts ensued. These involve companies and agencies like J-Biotech Environment Sdn. Bhd, National Hydraulics Research Institute Malaysia (NAHRIM), PROTON (Automotive) Berhad, KPJ Healthcare, PETRONAS (Oil & Gas) Melaka, Hospital Universiti Sains Malaysia (HUSM). The founding of Universiti Teknologi Malaysia Centre for Industrial and Applied Mathematics (UTM-CIAM) at the end of 2012 was a strong follow-up of the MISG 2011. It is a crucial transformation for the Malaysian mathematics for industry scene. This establishment creates a custom-built programme for active linkup particularly via the centre's flagship event in study group.

The Malaysian Mathematics in Industry Study Group is the centre's flagship event in study group and is organized in cooperation with Oxford Centre for Industrial and Applied Mathematics (OCIAM), University of Oxford. These are collaborative problem-solving workshops where more than seventy applied mathematicians, operational researchers and statisticians deal with real life problems brought by six private and public companies, and presented by the respective industrial representatives [3, 4]. These intense problem-solving sessions help to find out rapidly the main scientific and engineering issues, and mathematical challenges to be confronted. These MISGs have been a key tool for delivering the underpinning discipline of mathematics, operational research and statistics to difficult industrial problems. The meeting provides opportunities for linking the gap between academics and scientists from industry, encourages practical innovative knowledge and technology transfer and certainly occasions for young STEM graduates and postdoctoral fellows to explore possibilities of future employment. This article also summarizes the successful collaboration formed between academics and industry practitioners in solving specific problems from our national high revenue industries during the Malaysian MISG 2011 and 2014.

2 UTM Centre for Industrial and Applied Mathematics (UTM-CIAM)

UTM Centre for Industrial and Applied Mathematics (UTM-CIAM) is a research centre of excellence in Universiti Teknologi Malaysia. It is established with the strategic cooperation of Oxford Centre for Industrial and Applied Mathematics (OCIAM).

It was launched via a collaborative agreement which was signed on 12 December 2012 in the presence of the then Malaysian Minister for Higher Education at St. Anne College, University of Oxford. The establishment of UTM-CIAM is to facilitate the research cooperation with Malaysian industry and other disciplines including science, engineering and technology. This research would notably embed modelling and prepare to generate an innovative and optimal solution to be shared with the industry. In parallel with UTM-CIAM's vision to become a global renowned centre and to pioneer mathematics in the nation's industry, the main agendas of UTM-CIAM are to advance multidisciplinary research, to promote collaborative mathematical research with various disciplines, and to encourage practical applications of industrial and applied mathematics.

Mirroring the setting up of OCIAM, the objectives of UTM-CIAM are specifically laid down to ensure our capacity building in advanced research areas of industrial & applied mathematics, intensification of research & development (R & D) on joint industrial & applied mathematics with fields related to science, engineering and technology, advance multidisciplinary R & D by strengthening the collaborative research, modelling and formulation of optimal & innovative mathematical modelling solutions as the crucial enabling technology for the local industry (use of mathematical techniques: differential equations, operational research (OR) methods & statistical analysis) and last but not least in promoting practical & innovative applications of industrial and applied mathematics in industry to generate high quality applied research output.

Given this development (refer to Fig. 2), UTM-CIAM has launched many initiatives to persuade the government (policy makers), industry, academia & community user/civil society that the time is ready for change. Besides MISGs, the initiatives include the organization of International Seminar on Mathematics in Industry (ISMI)

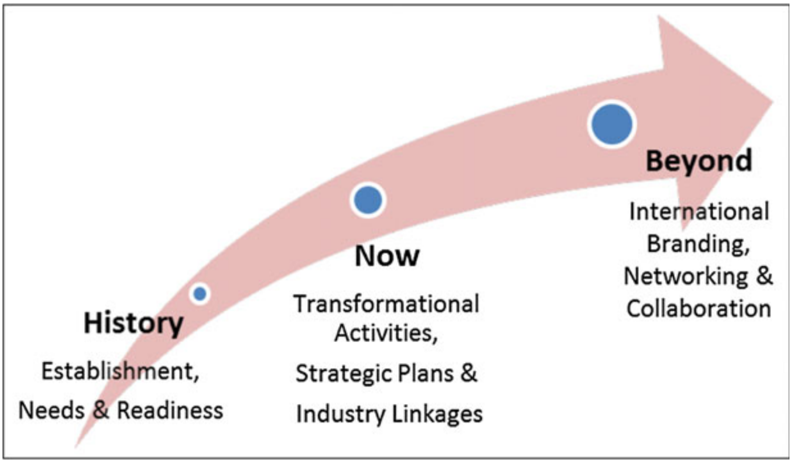

Fig. 2 UTM-CIAM pioneering Malaysian mathematics for industry

2013, National Seminar on Mathematics in Industry 2014, procurement of STEM research grants in the 2015 Public Private Research Network (PPRN) Malaysia, and paperwork to the Malaysian Ministry of Education on the national STEM graduate employability activities. The transformational activities, strategic plans and industry linkages are planned to bring about the important insight that industrial mathematics work is an increasingly central and necessary part of significant areas of investigation in medicine & healthcare, advanced design, environment, manufacturing, oil & gas, finance, agriculture and many more relevantly related to the Malaysian industries.

The targets for industrial linkages are chosen mainly from Small and Medium Enterprises (SMEs), Government Linked Companies (GLCs) types of industries and national research institutes with strong link with such industries. These industries contribute significantly to the national GDP. For example, in 2011 45 % of the government's budget was dependent on PETRONAS' dividend [5], in 2012 PROTON provides a fair share of the automotive sector contribution to the nation's GDP of 3.2 % [6], and similarly as for 2011 the KPJ Healthcare imparts a large share in the total healthcare spending in Malaysia amounted to 4.7 % of the country's GDP [7]. These industrial relationships can be further exploited with international linkages, networking and branding that UTM-CIAM is having with OCIAM UK, Centre for Mathematics in Industry (CMI), New Zealand, Institute of Mathematics for Industry (IMI), Kyushu University and Centre for Mathematical Modelling and Simulation, Institut Teknologi Bandung, Indonesia. The objective is to promote and foster the effective use of industrial mathematics and closely related knowledge and expertise (particularly related to STEM) in industrial, science & technology and management settings. More specifically, to perceive what is required by industry and business, to consider what is available and to discuss various plans to fill the gaps. The areas of mathematics are chosen based on the industrial problems being proposed in the MISGs which are predominantly in the areas of oil & gas and environment. These include differential equations, advanced mechanics (classical and fluid mechanics), mathematical modelling & simulations, OR methods and statistical analysis.

3 Transformation: Pioneering Malaysian Mathematics for Industry

In the efforts to increase research alliances with the industry, UTM-CIAM's researchers regularly visit potential industries to discuss the associated research projects and in the long run to strengthen the respective industrial partnership. Some of the industries that have been identified to currently retain active working relationship are NAHRIM, KPJ Healthcare, PETRONAS Melaka, J-Biotech Environment Sdn. Bhd, PROTON Berhad, Department of Civil Aviation (DCA), HUSM, Malaysian Agriculture Research & Development Institute (MARDI), and PROSPECT (Chemical processes). As a consequence, a Memorandum of Understanding (MOU) has been agreed between UTM-CIAM and HUSM, and UTM-

CIAM and J-Biotech Environment. Further MOUs are in the pipeline and soon will be activated.

As mentioned above, one of the main flagship activities being organized by UTM-CIAM is Mathematics in Industry Study Group (MISG). In 2014, UTM-CIAM collaborated with OCIAM, University of Oxford in holding the 2nd MISG Malaysia. Initially the industrial problems provided by the local industries are prepared and identified, and thus finally endorsed during an earlier discussion session between UTM-CIAM and OCIAM. Subsequently it is then determined that for MISG 2014, there are six industrial problems which would involve rigorous mathematical modelling. These include oxidation pond problem (J-Biotech Environment Sdn. Bhd), riverbank filtration problem (NAHRIM), electromagnetic shock absorber problem (PROTON Berhad), paddy field pest population problem (MARDI), blood flow at bifurcated artery (KPJ Healthcare), and water complex and heat integration in industrial process (PROSPECT). The study group is a rigorous workshop for problem solving where mathematician's expertise is being employed to overcome these real life problems proposed by the industry. In relation to that, many STEM academics with relevant backgrounds from OCIAM international network and local institutions are invited. Together with the industrial representatives, they would quickly help to determine the important scientific-industrial concerns and challenges of the study group during the problem solving sessions of the industrial problems.

As a result, MISG has given us the opportunity to end gradually the previous rift between academics, and industrial practitioners and scientists from the industries. It is shown practically that MISG has become a pragmatic platform to disseminate methods and emphases on the field of industrial and applied mathematics in numerous difficult industrial problems. We would like to emulate our European counterparts [8, 9] with excellent examples of European industry and mathematical sciences coming together to overcome various complex challenges of European industries face. Moreover in 2015, the new scheme is to organize the first Malaysia Mathematical Modelling Camp 2015 (MMMC 2015) before the annual MISG 2015. The aim of MMMC 2015 is to train and expose our young postgraduates and postdoctoral fellows to hands-on experiences on a broad range of real industrial problem-solving skills such as mathematical modelling & analysis, scientific computation and critical assessment of solutions. The problems to be considered are inspired by real problems that have arisen in industry.

In addition, we contemplate that our current and proposed programmes (e.g. MISG, MMMC, planned internships in industry) will have certain impact on the increase in our STEM graduate employability [10]. Undergoing these activities would facilitate our STEM graduates to be ready made for various sorts of industrial purposes and thus opening up a vast opportunity for young mathematical scientists to opt for other more satisfying careers in industry. Experience shows that successful and rewarding industrial problems require an interdisciplinary team and mathematical scientists can be indispensable contributors to this set up.

4 Action Plan and Roadmap

Based on Fig. 3 and the lessons learned from the first Malaysian MISG 2011, the action plan and roadmap for UTM-CIAM are strategized to realize the potential of industrial mathematics for breakthroughs and innovations in industrial and other societal problems. Our next steps are to continuously implement the flagship events including ISMI, MMMC and MISG. These are rooted in a natural and constant growth of activities which steps up on their strength over the six year period (2012–2018). All these developments are vital for the long term growth and competitive power, and demand an in-depth review of the overall progression of UTM-CIAM towards becoming a national higher institution centre of excellence (HiCOE) or simply a national referral point in industrial mathematics. This carries implications on the nature and scale of research and operational funding. The total amount of various funding secured so far by UTM-CIAM sums up to more than USD500K or RM1.65M (until early 2015). Its ambitious aim is to become the national dedicated one-stop centre to coordinate and facilitate the needed interactions in the domain of application-driven mathematical research and its development for innovations in industry, science and society. A national centre implies that other researchers in the field of industrial mathematics from other Malaysian universities will be able to link-up with the local industries via UTM-CIAM's activities, particularly ISMI, MMMC and MISG. For ISMI 2013, MISG 2011 & 2014, almost a third of the academics came from other Malaysian universities including Universiti Sains Malaysia (USM), Universiti Malaya (UM), Universiti Malaysia Perlis (UNIMAP), Universiti Putra

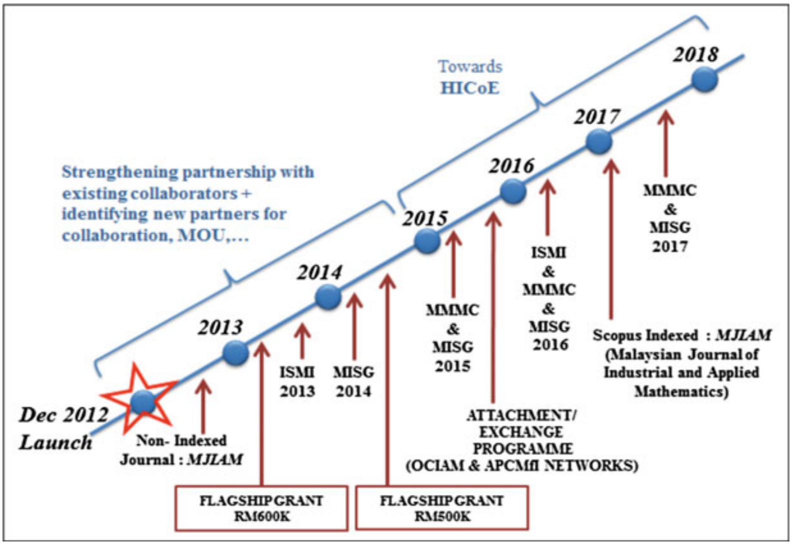

Fig. 3 Roadmap (2013–2018)

Malaysia (UPM) and Universiti Malaysia Terengganu (UMT). The MISG 2015 will be co-organized by UPM. The local researchers also will be able to take part in the planned attachment and exchange programmes, which will be made available via networks of OCIAM and APCMfI (Asia Pacific Consortium of Mathematics for Industry; refer to Sect. 6).

Undoubtedly, the continuous multidisciplinary research and novel mathematical, operational, statistical and computational methods are required to provide necessary tools and methods of solution for Malaysian industrial innovation and competitive edge. These will be documented in our Malaysian Journal of Industrial and Applied Mathematics (MJIAM). Although the mathematics-industry interaction has reached an acceptable level in some countries of the European Union and Australia-New Zealand, it is far from being equally developed in Malaysia and South East Asia. Thus the action plan and roadmap of UTM-CIAM are strategized to address these issues directly.

5 Industry Collaboration/Linkages

In recent years, university-industry linkages in Malaysia have enlarged given the rapid pace in knowledge generation as well as the escalating costs associated with R & D activities. UTM-CIAM has recognized that collaborations with industry and other external parties bring with them benefits to teaching and skills development; access to funding and empirical data from industry; reputation enhancement; application of knowledge; opportunities for talent development by both students and staff; and promotion of entrepreneurship. Concurrently with the Malaysian Ministry of Education's initiatives in promoting linkages and knowledge transfer, UTM-CIAM efforts in creating partnerships and collaborations with industry need to be streamlined and enhanced.

In order to strengthen the industrial linkages, UTM-CIAM plans to embrace the "*Quadruple Helix* (QH) *innovation model*", which refers to a model or framework describing the interaction or innovation cooperation between four clusters, namely government, industry, academia & community user/civil society. A general definition of the QH innovation model [11] refers to an innovation cooperation model or innovation environment in which users, private firms, universities and public authorities cooperate in order to produce innovations. These innovations can be anything that is considered useful for the partners in innovation cooperation, for example, technological, social, product, service, commercial, non-commercial, private-sector and public-sector innovations. Applying this QH innovation model implies that UTM-CIAM's linkage between the four clusters would involve interaction in the forms of *relation* (involving contract research, consultancy, etc.), *mobility* (involving research training, modelling workshop, study group, etc.), *transfer* (involving copyright, commercialization, etc.,) and *formality* (involving MOU, MOA, LOI, etc.). This framework has been used to describe the inner workings of regional innovation systems. According to [12], this framework already encourages the perspective of the knowledge society and of knowledge democracy for knowledge generation and innovation; and the sustainable development of a knowledge economy requires a co-evolution with the knowledge society. Thus this description suits well with UTM-CIAM's action plan and roadmap in strengthening, sustaining and identifying further interactive partnerships with industries.

The following notes are given as solvable samples of brief equation-free reports on two industrial problems in the MISG 2014 Malaysia.

5.1 Case Study on Oxidation Pond

The oxidation pond that becomes the pilot scale study is Taman Timor Oxidation Pond, Tampoi, Johor, Malaysia estimated about 1,909 square meters and has a depth about 1.5 meters and total volume of water about 2,864.13 cubic meters or 2,864,125.13 litres. To improve the efficiency of the water treatment, beneficial microorganism based product (called mPHO, a bio-product used to improve water quality) has been added to the pond to provide efficient removal and break down of solid content of influent and pathogens, which are generally not sufficiently removed by oxidation pond. The product mPHO is made from the selected species of phototrophic bacteria (PSB). About 1,375 litres of mPHO have been applied to the Oxidation Pond, throughout 3 months of treatments. Samples were collected at two points of the pond which are CP1 (influent and application of mPHO) and CP2 (effluent). The microbial approach can help in purifying heavily polluted water especially in the area that is exposed to sunlight. The ability of mPHO to photosynthesize and photometabolize many organic substances may help to reduce BOD (biological oxygen demand), COD (chemical oxygen demand), TSS (total suspended solids), NH3-N (ammoniacal nitrogen) and bacteria (E. coli and Coliform) content in wastewater and increases the amount of DO (dissolved oxygen) in the pond. Therefore, the right amount of mPHO must be determined to ensure that sufficient dose is added, thus maintaining its efficiency and prevent excessive use.

However, in this study the industrial partner wants to investigate the ability of mPHO in reducing the population of E. coli and Coliform in the pond. This is because that microorganism (E. coli and Coliform) is the most harmful living organism in the pond that may affect human's health. To solve this problem, we have built a model that includes the interaction of these three microorganisms (PSB, E. coli and Coliform).

Oxidation pond techniques have practically proved to be effective for wastewater treatment process (WWTP) because of their low construction and operating cost. Cumbersome sampling is required to monitor the dynamics of the WWTP which also involves enormous costly work. Stochastic model accommodating the correlation between the amount of phototrophic bacteria in mPHO and pollutant (bacteria E. coli and Coliform) existing in oxidation pond is developed to facilitate the analysis of this process. This study presents a stochastic model for an oxidation pond to investigate the effect of mPHO on the degradation of pollutant. The model consists of a system of stochastic differential equations with coupled reaction equations for the pollutant and phototrophic bacteria. The parameters of the model is estimated using the real data collected from the oxidation pond located in Taman Timor, Johor, Malaysia to illustrate a real life application of this model. The simulation results provide a better understanding of the ecological system in the oxidation pond.

5.2 Case Study on Groundwater Modelling

In tropical countries like Malaysia where the rainfalls continuously recharge river flow, the main source of dependable water supply is essentially river water. However, as development and economic activities spread, the management of water resources can be very critical due to increased demand as well as environmental degradation. Pollution of rivers has made surface water unsuitable for sources of raw water for treatment and in certain cases has caused the treatment costs to rise unexpectedly. One of the alternative ways to improve dependable clean potable water supply that is being considered is through Riverbank filtration (RBF) technology as a second source of water supply to guarantee clean and dependable watersupply solution without neglecting the polluted surface water.

Riverbank filtration (RBF) is a natural technique for surface water treatment, based on the natural removal of pollutants from water during its transfer through the aquifer to pumping well. This technology is applied in USA and several European countries. Recently, RBF technique has been applied by our industrial partner for the first time in Malaysia in a pilot project conducted in Jenderam Hilir, located in Langat Basin, Selangor, Malaysia. This approach had been approved to be a very effective technology that reduces pollutants concentration and it has potential benefits for drinking water supply in Malaysia. To manage and operate RBF system efficiently, it is extremely important to evaluate the potential for contamination of drinking water wells by river pollution.

To manage and protect the water supply, transport processes need to be predicted by using the RBF method. This study specifically simulates the groundwater flow and contaminants transport induced by pumping well and investigates the evolution of the water chemistry during bank-filtrations systems.

Riverbank filtration (RBF) [13] is a natural technique for surface water treatment, based on the natural removal of pollutants from water during its transfer through the aquifer to pumping well. In this study a mathematical model is used to simulate three major processes related to RBF which are: (1) groundwater flow and contaminants transport from river towards the pumping well (2) arrival time needed by contaminants to reach the well and (3) evolution of water chemistry due to microbial activity. Whiles the first and second problems were solved numerically by using MODFLOW, the third problem was solved analytically. MODFLOW simulation highlighted the capture zone influenced by each pumping well. Also it was found that the contaminant needs 75 days to reach the pumping well. Furthermore, the analytical model for the third problem showed that NO_3 and O_2 were consumed within 10 cm of the aquifer whiles SO_4 consumed within 30 cm.

The impact of these MISG efforts is to put forward workable and practical solutions to the respective industries in order for the companies to adhere to certain best practices, particularly in implementing their standard operating procedures, cost effective and optimal measures on the specific problems. Post MISG collaborative endeavour requires ongoing follow-ups on the specific problems, ensuring a more developed solution will be finally obtained. Besides, the ongoing venture will assure a long-term university-industry relationship.

6 Beyond Malaysian Mathematics for Industry

In order to progress beyond the Malaysian landscape and to strengthen the partnership between UTM-CIAM and the industries globally, UTM-CIAM has been selected as the sole Malaysian representative at a special meeting in Canberra, Australia on 31 Mac–2 April 2014. This encounter discussed the formation and launching of Asia Pacific Consortium of Mathematics for Industry (APCMfI), where the major interest is on mathematics for industry. The centre of APCMfI is agreed to be located at the Institute of Mathematics for Industry, Kyushu University, Fukuoka, Japan. The meeting and discussion basically prepared UTM-CIAM for the next level of engagement. The formation of APCMfI has obtained the strong support and encouragement from China, Korea, Malaysia, Singapore, Australia, New Zealand and also Japan. UTM-CIAM strongly hopes that this affiliation would bring us to another level of commitment which goes beyond the Malaysian mathematics for industry.

In the face of challenges as one of the high-tiered national research universities and to increase her capacity and capability, Universiti Teknologi Malaysia (UTM) is compelled to reassess her current R & D ecosystem. Strengthening the competitive advantage and increasing the benchmark performance in R & D locally and globally requires a rethinking process of research, innovation and commercialization. The strategy adopted and implemented is the consolidation and reorganization of UTM centres of excellence (COE) into a Research Institute. It is now acknowledged that UTM-CIAM will be consolidated and reorganized as an entity within a research institute, namely the Ibnu Sina Institute for Scientific and Industrial Research (Ibnu Sina ISIR). The Ibnu Sina ISIR consists of six COEs and forty permanent research staff with various backgrounds and research inclinations, as portrayed in Fig. 4. UTM-CIAM deeply foresees this as another forward look initiative and level of engagement to strengthen the current collaboration and consolidation beyond Malaysian mathematics for industry.

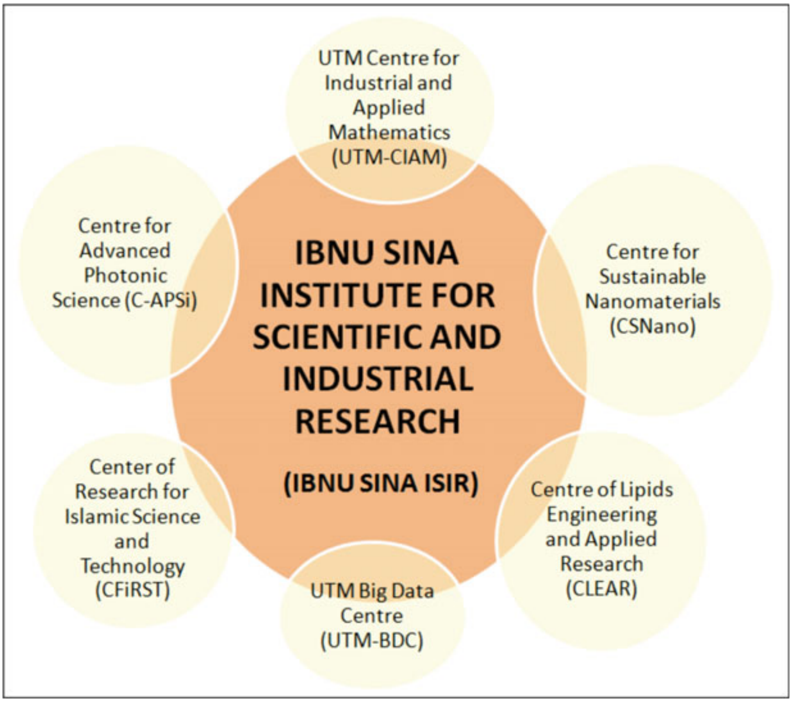

Fig. 4 Strengthening collaboration & consolidation beyond mathematics, where Islamic science is the concept as discussed in Aziz [14]

7 Conclusion

From the Malaysian perspective, the forward look at mathematics and industry arose from the firm belief that UTM-CIAM has the potential to become an important economic and STEM skilled human capital resources for the Malaysian industry, helping its innovation and hence its capacity and capability of competing on the global market. The creation of UTM-CIAM is indeed to steadily close the gap between the industrial mathematicians and the industrialists, government, and civil society. Thus based on the above discussions, the streamlined programmes and initiatives set out by UTM-CIAM, the future plan is to generate more affirmative impact and response via the quadruple helix innovation model mechanism. Besides mathematics, UTM-CIAM is increasingly reliant on science, technology and engineering to help boost innovation and economic growth and to improve our quality of life [15]. With this dependence comes a growing need for improved education and training in STEM subjects including mathematical modelling, operational research and statistics, both for the scientific and technical workforce and for the general public in a gradually more technological and digital world.

Furthermore we hope that from these programmes and initiatives, the hundreds of the Malaysian SMEs, multinational GLCs and the private ones will become progressively more aware of the significance of the applications of mathematics for their commercial survival. These Malaysian industries should now come to terms and appreciate that industrial mathematics is one of the keys to expand and sustain their economies and profitability. Moreover, the professional and academic associations, including the Malaysian Mathematical Science Society (PERSAMA) and the Malaysian Academy of Mathematical Scientists, ought to be proactive in order to play a major role as catalysts in influencing the culture and development of industrial mathematics and related mathematics-industry interface. These can be done by actively supporting high-profiled activities such as conferences, MISG workshops, and weekly industrial problem solving gatherings in the field of industrial mathematics.

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Group Theory Methods in Virology: Landau Density Wave Approach

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Abstract Viruses are organized biological nanosystems which display high level of spatial organization. In the present work we focus on the group theory methods application to the problems of virus self-assembly and resulting viral structure formation. The approach is based on the successive application of methods of representation theory for continuous and discrete groups and invariant theory for the groups not-generated by reflections. It generalizes the Landau density wave theory of crystallization to the case of compact crystal-like manifold assembly. To compare the predictions of the theory with the available cryoelectronic microscopy data we use the calculated density distribution functions which generate the protein positions on a spherical surface of the cage protecting viral genome. We also discuss the relation between density distribution functions and viral infectivity.

Keywords Group theory · Virology · Density waves · Self-assembly · Icosahedral viruses · Crystallization

1 Introduction

Viruses occupy the "gray area" between living and non-living matter. In contrast with other forms of living matter viruses cannot replicate independently, they need a host cell and its biosynthetic machinery to reproduce new viral particles. Their genetic material is vulnerable to degradation before the infection into the cell can occur. Therefore, it is protected by the viral protein shell (capsid) which encloses the genome. Though virus capsid formation involves biologically specific events, some

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steps of the self-assembly are similar to passive physical processes and show universal features. All viruses follow some common scenario: they deliver viral genomic material into host cell, subvert cell's biosynthetic mechanisms into producing viral genome and proteins, then, new viral particles self-assemble in the infected cell, and finally, new generation of virus leaves the cell [1]. Genomic material of viruses is strongly diversified: it can be DNA or RNA (both "+" and "-" type), single- or double-stranded, linear or circular, one or several copies. On the contrary, capsid structure is quite universal. Viral capsids are made of many copies of identical subunits (one or few proteins) self-assembling in a two-dimensional (2D) shell. The positions and orientations of subunits display high level of spatial organization. With a typical diameter of the order of 50 nm and the regular protein organization, capsids represent nano-systems well-suited to modern structural methods of study like synchrotron radiation diffraction or cryoelectron tomography [2]. Recent structural data obtained due to the progress of cryoelectronic technique rise a whole number of questions concerning unconventional positional order of subunits in the shell, thermodynamics and physical mechanisms of the self-assembly.

From the point of view of geometry, viral capsids are divided into two wide classes: (i) open cylindrical structures with helical rod-like protein arrangement; (ii) spherical ones. Several viral families constitute notable exception to this classification. For example, capsids of many retro-viruses including HIV are conical shells with continuously varying curvature. In the present work we focus on viruses with compact spherical topology, on successive steps of the spherical virus assembly process, and on the underlying physical mechanisms and mathematical formalism. We are interested mainly in the first step of the process. At this step a solid spherical protein shell self-assembles from the aqueous solution of individual proteins.

In their pioneer work Crick and Watson (CW) [3] stated that viruses with spherical topology should have the symmetry (but not necessarily the shape) of one of regular polyhedra. Using more detailed X-ray diffraction data Caspar and Klug (CK) precised that spherical capsids adopt icosahedral point symmetry [4]. Decades of experimental studies showed that lateral, strongly orientation-dependent type of capsid protein interaction, together with intrinsic curvature and, especially, asymmetry of capsid proteins define particular docking preferences. Consequently, protein interaction results in specific geometric arrangements and influences the capsid assembly phenomenon. Both CW and CK insisted on the fact that typical viruses have very small genome (with respect to any other biological system, i.e. bacteria). Thus, it can code only for a few proteins, and among them there is typically only one "coating" protein. Viral capsid is then constituted with multiple copies of the same coating protein. They also stressed that the interaction of identical proteins should lead to identical local environments, including local orientational and positional order and local chemical bonding, and proposed to construct the icosahedral shells possessing these properties.

Due to these advances the main problems in the field of physical structural virology could be formulated: (i) *how to construct a regular 2D shell with the icosahedral symmetry formed by multiple copies of identical asymmetric proteins in identical local*