Student enrollment allocation into academic programs using preemptive goal programming.

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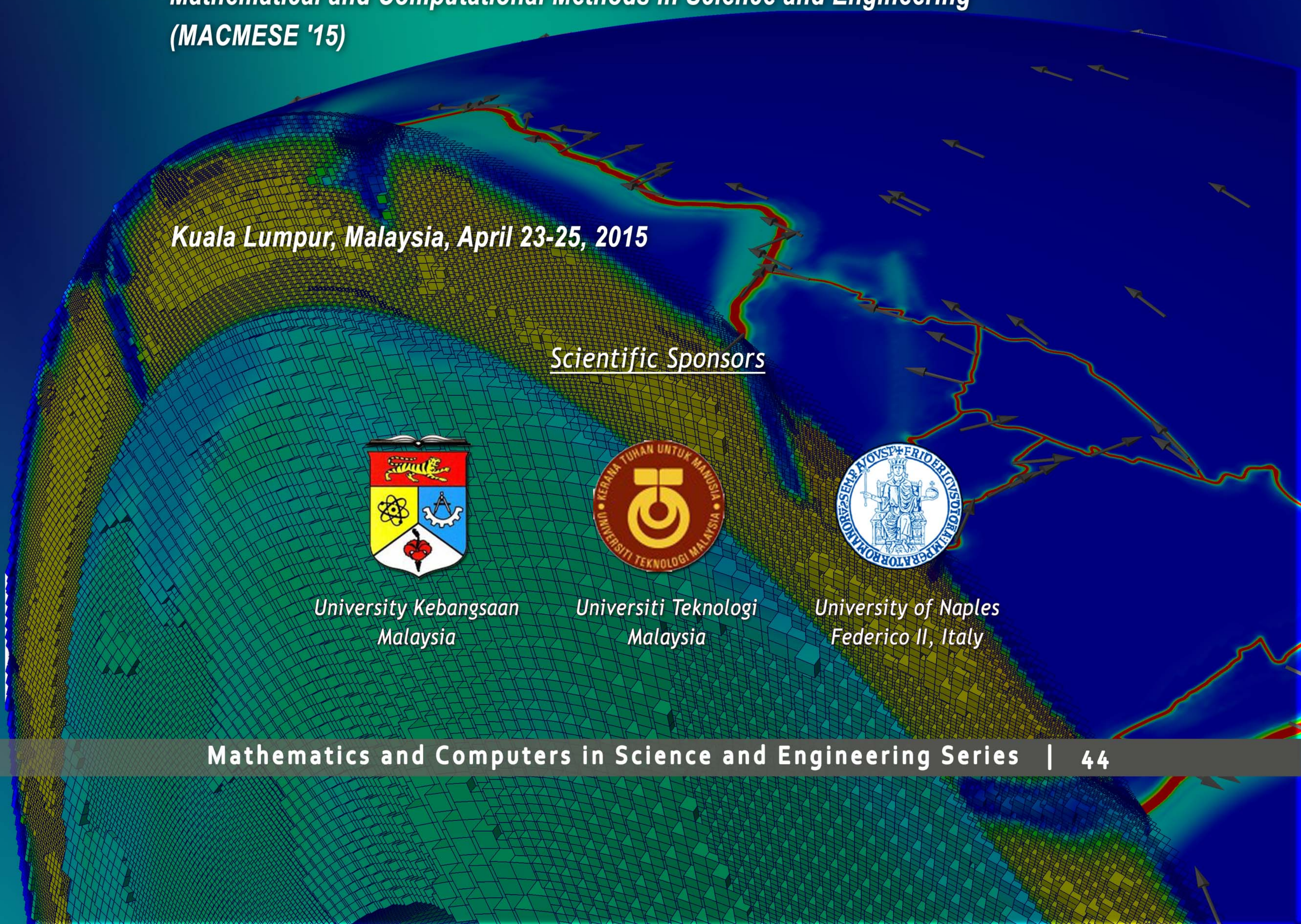

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Preface

This year the 17th International Conference on Mathematical and Computational Methods in Science and Engineering (MACMESE '15) was held in Kuala Lumpur, Malaysia, April 23-25, 2015. The conference provided a platform to discuss mathematical methods and computational techniques or applications of known mathematical methods and computational techniques etc. with participants from all over the world, both from academia and from industry.

Its success is reflected in the papers received, with participants coming from several countries, allowing a real multinational multicultural exchange of experiences and ideas.

The accepted papers of this conferences are published in this Book that will be sent to international indexes. They will be also available in the E-Library of the WSEAS. Extended versions of the best papers will be promoted to many Journals for further evaluation.

Conferences such as this can only succeed as a team effort, so the Editors want to thank the International Scientific Committee and the Reviewers for their excellent work in reviewing the papers as well as their invaluable input and advice.

The Editors

Table of Contents

Plenary Lecture 1

Signaling Problem of Wave Evolution

Professor Edi Cahyono
Department of Mathematics
University of Halu Oleo
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Abstract: We consider surface wave evolution. At an initial point the wave profile is given as a prescribed signal. For practical needs in hydrodynamics laboratories, the waves are usually measured downstream at several points. In the case of traveling waves, the signals downstream are merely translated temporally from the ones at the initial points. In general, this does not occur. Waves may provide much different signal profiles at different points.
We focus on waves governed by a KdV type equation. We present the changes of the wave profiles at several points. The waves which are the solutions of KdV type equation are computed analytically by applying perturbation method. The solution is in a series expansion of two parameters, i. e. amplitude and frequency difference. We show that these parameters are responsible for the profile change of the solution at several points. The profile change is mainly due to the so-called side band interactions.

Brief Biography of the Speaker: He was awarded a Doctor in Applied Analysis and Mathematical Physics University of Twente, the Netherlands in 2002. Upon completion of his PhD degree, he was appointed as a Lecturer in the Department of Mathematics, Universitas Halu Oleo, Kendari Indonesia. In 2010 he was promoted to Professor of Industrial and Applied Mathematics. His main research areas are focused on Partial Differential Equations and applications. For the case of diffusion equation, he has applied it for modeling of wood drying in an industry. Currently, he has been working on the relation of fundamental solution type with temporal probability density function of stock, currency and index dynamics.

Plenary Lecture 2

Several Equivalent Relations about Variational Inequality Problems

Professor Zili Wu
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Abstract: We consider equivalent relations between the Gateaux differentiabilities of two gap functions of variational inequality problems. Some equivalent conditions for their locally Lipschitz property are also presented. Equivalent condition for the relevant mapping to be pseudomonotone+ on relevant solutions sets are obtained. Based on the above results, we characterize the weak sharpness of the solutions of variational inequality problems in terms of error bounds of two gap functions. Furthermore we show that some algorithms for solving variational inequality problems possess finite convergence property.

Plenary Lecture 3

Big Data Algebra: A Rigorous Approach to Big Data Analytics and Engineering

Professor Yingxu Wang
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Abstract: Data are an abstract representation of the quantity of real-world entities and mental objects. Big data are extremely large-scaled heterogeneous data in terms of quantity, complexity, semantics, distribution, and processing costs in computer science, information science, cognitive informatics, web-based computing, cloud computing, and computational intelligence. Big data science studies the properties, theories, mathematical means, and methodologies of big data. Big data engineering is systematical analytic technologies for efficiently dealing with the inherent complexity and exponentially increasing demands in big data representation, acquisition, storage, organization, manipulation, searching, retrieval, distribution, standardization, consistency, and security.
This keynote lecture presents a big data algebra as a novel denotational mathematics for formal big data analytics in big data science and engineering. The cognitive foundations of data, information, knowledge, and intelligence are explored. A mathematical model of big data is formally introduced. Based on it, a set of algebraic operators on formal big data models, such as the formal big data analysis, inference, mining, induction, and fusion operators, is rigorously elaborated. This leads to the algebra for big data modeling, analyses, mining, information elicitation, knowledge representation, and intelligence inference. A wide range of applications of big data algebra are identified in the contemporary fields of big data science/engineering, cognitive informatics, knowledge mining, neurocomputing, human memory mechanisms, cognitive computing, machine learning, semantic computing, cognitive linguistics, cognitive systems, computational intelligence, artificial intelligence, cloud computing, and intelligent systems.

Brief Biography of the Speaker: Yingxu Wang is professor of cognitive computing, brain science, and denotational mathematics, President of International Institute of Cognitive Informatics and Cognitive Computing (ICIC, http://www.ucalgary.ca/icic/) at the University of Calgary. He is a Fellow of ICIC, a Fellow of WIF (UK), a P.Eng of Canada, and a Senior Member of IEEE and ACM. He received a PhD in computer science from the Nottingham Trent University, UK. He was visiting professors (on sabbatical leave) at Oxford University (1995), Stanford University (2008), UC Berkeley (2008), and MIT (2012), respectively. He is the founder and steering committee chair of the annual IEEE International Conference on Cognitive Informatics and Cognitive Computing (ICCI*CC) since 2002. He is founding Editor-in-Chief of Int. Journal of Cognitive Informatics & Natural Intelligence (IJCINI), founding Editor-in-Chief of Int. Journal of Software Science & Computational Intelligence (IJSSCI), Associate Editor of IEEE Trans. on SMC (Systems), and Editor-in-Chief of Journal of Advanced Mathematics & Applications (JAMA). Dr. Wang is the initiator of a few cutting-edge research fields such as cognitive informatics, denotational mathematics (concept algebra, process algebra, system algebra, semantic algebra, and inference algebra), abstract intelligence (αI), cognitive computing, cognitive learning engines, cognitive knowledge base theory, and basic studies in software science, neuroinformatics, fuzzy mathematics, cognitive linguistics, and computational intelligence. He has published 400+ peer reviewed papers and 28 books in cognitive informatics, denotational mathematics, cognitive computing, software science, and computational intelligence. He is the recipient of dozens international awards on academic leadership, outstanding contributions, best papers, and teaching in the last three decades.

Student enrollment allocation into academic programs using preemptive goal programming

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Abstract: A preemptive multi-criteria model is built to optimize the distribution of students into academic programs of a department by taking into account the limits of space capacity, financial allocation, the number of instructors and affirmative action quotas. Each constraint has a priority level and a weight attached. This model is applied to the School of Mathematical Sciences, Universiti Kebangsaan Malaysia. The results are then compared to that of the current allocation using the weighted mean absolute percentage error. The successful application demonstrates the ability of the preemptive model to comply with the student intake requirement and constraints of academic programs in the department.

Key-Words: Affirmative action, allocation, constraints, goal, priority, weighted mean

1 Introduction

Goal programming has been used extensively in many areas such as in management for Malaysian crops [1-4], portfolio of Malaysian stock market [5], management of tourism activities [6], library acquisition and funding allocation [7-8], food product distribution [9] and bakery production [10]. Currently preemptive goal programming models are being applied in minimization of energy consumption on multiprocessor platforms [11], fuzzy investment decisions [12], flood flow model [13], and joint decision making of inventory [14].

Earlier modeling approaches in institutions of higher learning tend to be directed towards aggregate planning of human, financial, and physical resources in the higher levels of academic administration planning [15-19]. However the main academic thrusts of the institutions are left out. Some departmental level modeling techniques dealing with faculty-course assignment required the development of complex utility functions to express faculty preferences for certain courses [20-23]. The required time consuming modeling efforts, and the complexity and the time necessary to develop utility functions of faculty preferences could however limit their application when used on a practical reoccurring basis on departmental level in an organization of higher education [24].

In order to emphasize the thrust of academic institutions, academic administrators have to determine the number of students to be enrolled based on the expertise of academic staff, student capacity of each program, admission policies and create a racial balance in each program based on the affirmative action policy to be dealt with every semester. Administrators' decisions should indicate the thrust of the academic faculty, limited infrastructure, and the affirmative action requirement for government funded public universities.

In this paper, a preemptive goal programming model is developed which will optimize the allocation of students into academic programs taking into account the expertise of academic staff, student capacity of each program, admission policies and financial allocations. It is further refined to create a racial balance in each program based on the affirmative action policy and provide a fair distribution of student-to-faculty ratio. Weights will be used to apportion the students into academic programs in the department that will reflect the research thrust of the department. The weighted deviations are then given priority levels in the objective function to emphasise the ranking of goals. Error analysis is established for the preemptive model based on the deviations from the aspired levels and then compared against those of the current allocation using a weighted mean absolute percentage error (MAPE) analysis [25].

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2 Model Development

Listed below are the input parameters, constraints and the objective function of the model in allocating students of a department, the School of Mathematical Sciences, to its three academic programs of mathematics, statistics and actuarial science, for its three years undergraduate study.

Input Parameters

c_j = capacity of of first year students in program j
r_j = student to faculty ratio required for program j
q_j = minimum ratio of native students over the total students entering program j
z_j = number of drop-out native students from program j
t_j = total capacity of students in program j proportionate to the number of classes
e_j = number of students enrolling into year two
h_j = number of students enrolling into year three

Variables

x_j= number of natives admitted into program j
y_j = number of non-natives admitted into program j
a_j = total number of first years in program j
d_j = total number of students enrolled in program j
f_i = total number of students in department i
l_j = number of faculty required for program j
X = total number of first year native students admitted into the department
Y = total number of non-native students admitted into the department
A = total number of first year students admitted into the department.

Constraints

The constraints involved in the School of Mathematical Sciences with three programs are as follows.

$$\sum_{j=1}^{M} x_j = X_i, \quad \sum_{j=1}^{M} y_j = Y_i, \quad \sum_{j=1}^{M} a_j = A_i, \qquad (1)$$

where $M = 3$, $X_i = 134$, $Y_i = 88$ and $A_i = 222$.

For $j = 1,\ldots, 3$, we have

$$a_j - x_j - y_j = 0, \qquad (2)$$

$$a_j + d_{1j}^- - d_{1j}^+ = c_j, \qquad (3)$$

where c_1, c_2 dan c_3 are 90, 80 and 70 respectively.

$$d_j + d_{2j}^- - d_{2j}^+ = t_j, \qquad (4)$$

where t_1, t_2 dan t_3 are 260, 220 and 190.

$$x_j - z_j - q_j a_j + d_{3j}^- - d_{3j}^+ = 0, \qquad (5)$$

where q_1, q_2 dan q_3 are 0.80, 0.49 and 0.48.

$$d_j - a_j = e_j + h_j \qquad (6)$$

where $e_j + h_j$ are 172, 134 and 121.

$$f = \sum_{j=1}^{3} d_j \text{ is } 649 \qquad (7)$$

$$r_j . l_j - d_j + d_{4j}^- - d_{4j}^+ = 0, \qquad (8)$$

where r_1, r_2 and r_3 are 14, 12 dan 26 respectively.

$$l - \sum_{j=1}^{3} l_j = 0 \qquad (9)$$

The students cost in a program does not vary much to other programs within the same department since they share the same equipment and facilities. Hence the budget cost constraint is redundant and thus omitted.

Objective function

The criterion of optimization aims at maximizing the allocation of students accepted into the department by

$$\max \sum_{j=1}^{M} a_j = \sum_{j=1}^{M} x_j + y_j \quad \text{first year admission} \qquad (10)$$

$$\max \quad f = \sum_{j=1}^{M} d_j \quad \text{enrolees in department} \qquad (11)$$

$$\min \sum_{j=1}^{M} x_j - q_j a_j \quad \text{affirmative action quota} \qquad (12)$$

$$\min \sum_{j=1}^{M} l_j \quad \text{number of faculty} \qquad (13)$$

Note that the objective function in this case, has to be rewritten as a single function of deviations and prioritized accordingly.

Minimize

$$Z = P_1 \sum_{j=1}^{M} k_{1j}\left(d_{1j}^- + d_{1j}^+\right) + P_2 \sum_{j=1}^{M} k_{2j}\left(d_{2j}^- + d_{2j}^+\right) + P_3 \sum_{j=1}^{M} k_{3j}\left(d_{3j}^- + d_{3j}^+\right) + P_4 \sum_{j=1}^{M} k_{4j}\left(d_{4j}^- + d_{4j}^+\right) \qquad (14)$$

Note that the weights k_{ij} have values 1, 2 or 3. In our case the first priority goal P_1 was admission requirement, the second priority goal P_2 was the capacity requirements of each program, the third priority goal P_3 was the affirmative action ratio whilst the fourth goal P_4 was student-staff ratio. The values of the weights of deviations are based on their rank, the higher the rank the higher would the value of the weight be.

$$k_{11} = 2, k_{12} = 3, k_{13} = 1, k_{21} = 3, k_{22} = 2, k_{23} = 1, k_{31} = 1, k_{32} = 3, k_{33} = 2, k_{41} = 2, k_{42} = 1, k_{43} = 3. \qquad (15)$$

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3 Analysis of Results

The output obtained with regard to the enrolment into three academic programs of Mathematics, Statistics and Actuarial Science in the School of Mathematical Sciences is shown in Table 1.

Note that from the third column of the Table 1, the model suggest a mix of 39 native and 41 non-native students to be admitted into the statistics program in order to fulfil the admission capacity of 80 students. This is due to the highest priority and weightage given towards this requirement. Compare these values to that of the last column where the mix of 26 native and 28 non-native students will only fill up 54 of the 70 places available.

This situation arises because filling up the capacity of the actuarial program is given least priority, compared to that of mathematics or statistics. The fifth row displays the number of staff required in each program corresponding to the total number of students in that particular program. The values of the deviational variables with their priorities and respective weights are listed below. Note that the objective value is 84.16.

First priority is student admission, with declining weights in Statistics, Mathematics and Actuary. The corresponding deviational variables are $d_{12}^- = 0$, $d_{11}^- = 2$, $d_{13}^- = 16$. Note that the preemptive model ensures that admission into the Mathematics program is optimum. The Actuary program on the other hand has an increased underachievement of 16 students since admission into it is accorded the least weight.

Second priority is student capacity with declining weights in the Mathematics, Statistics and Actuary programs. The corresponding deviational variables are $d_{21}^- = 0$, $d_{22}^- = 6$, $d_{23}^- = 15$. Note that the preemptive model optimizes student capacity of the Mathematics program with the highest weightage as indicated by the value of d_{21}^-. The high underachievement d_{23}^- of the student capacity of the Actuary program is because it has the least weight.

Third priority is affirmative action with declining weights in the Statistics, Actuary and Mathematics program. The corresponding deviational variables are $d_{32}^- = 0.2$, $d_{32}^+ = 0$, $d_{33}^- = 0$, $d_{33}^+ = 0.08$, $d_{31}^- =1.4$, $d_{31}^+ = 0$. The model indicated a small deviation from the affirmative action mix. It maintained that no more than two students will exceed the required mix of the affirmative action requirement.

Fourth priority is the student-faculty ratio with declining weights in the Actuary, Mathematics and Statistics programs, with $d_{43}^- = 0$, $d_{43}^+ = 7$, $d_{41}^- = 0$, $d_{41}^+ = 6$, $d_{42}^- =0$, $d_{42}^+ = 2$. Note that the student-faculty ratio has been a little bit overachieved in both the programs of Actuary and Mathematics as

Table 1: Results of the Preemptive Model

Departmental programs	Math	Stats	Actuary
Number of first year native students	69	39	26
Number of first year non-native students	19	41	28
Number of first year students to be admitted	88	80	54
Number of academic staff in each program	19	18	7
Number of students in each program	260	214	175

Table 2: Error Calculations for the Preemptive Model

Priority	Weights w	Aspiration X	Preemptive Model	Error	Current	Error
	2	90	88	2	82	8
1	3	80	80	0	78	2
	1	70	54	16	62	8
	3	260	260	0	254	6
2	2	220	214	6	212	8
	1	190	175	15	183	15
	1	0.80	0.7841	0.0159	0.8049	0.0049
3	3	0.49	0.4875	0.0025	0.4872	0.0028
	2	0.48	0.4815	0.0015	0.4839	0.0039
	2	14	13.68	0.32	13.37	0.63
4	1	12	11.89	0.11	11.78	0.22
	3	26	25.00	1	26.14	0.14

indicated by d_{43}^{+} and d_{41}^{+}. These mean that the student-faculty ratio is less than 26:1 and 14:1 respectively. In other words, an additional number of seven students in the Actuary program and an additional six students from the Mathematics program will be required to meet the ratio of those two programs.

Error analysis is established based on the error deviations from the aspired levels, of our model and those of current values as indicated in Table 2 by using the weighted Mean Absolute Percentage Error (MAPE) analysis [25].

For our preemptive model, the weighted MAPE

$$\frac{\sum w_i \frac{|e_i|}{X_i} \times 100}{\sum w_i} = \frac{0.618205386}{24} \times 100 = 2.576\ \%.$$

Comparing this value to the MAPE of the current practice which is 2.965 %, we note that the MAPE value for our preemptive allocation model gives a better result which is closer to the aspiration values compared to that of the current allocation practice. If we are to categorize the MAPE values according to priorities, then the weighted MAPE values can be found as in Table 3.

Table 3: MAPE values based on priorities

Priorities	Model %	Current %
Student admission	4.5503	6.1177
Student capacity	2.2249	2.9800
Affirmative action	0.6905	0.6881
Student-staff ratio	2.8378	2.0748

Note that the first priority weighted MAPE value of the model is significantly lower by a third of the current value, while the second priority weighted MAPE value is reduced by a fourth of the current value. Consequently, there is a small percentage rise of the MAPE values of the second and third priority.

4 Conclusion

We have successfully obtained the results of the preemptive goal programming and error analyses in the form of weighted Mean Absolute Percentage Error (MAPE) were conducted. It is shown that the MAPE values of our model are less than the MAPE values of the current practice. These show that our model adhered closely to the requirements of aspiration levels. Based on the results obtained, we were able to undertake an in-depth discussion on the deviation variables based on the given priorities and relate the findings to the weights and priority levels assigned to these variables. From the discussion of these deviational variables, we can verify that the results of the models conform to our requirement of fulfilling the highest priority goals in accordance to the corresponding weights of the three programs in the School of Mathematical Sciences. Thus we believe the model can be used for policy-making in the decision process of future allocation of students to academic programs of the department. The model can be further extended to allocation of students into academic faculties if additional constraints regarding budget allocation are taken into consideration.

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