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AN INTRODUCTION TO CUMCM

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Abstract–*The China Undergraduate Mathematical Contest in Modelling (CUMCM) is a national event held annually. Teams of up to three undergraduate students investigate, model, and submit a solution to one of two simulated real-word problems in engineering, management, etc. The aim of the contest is to expose students to the real-world challenges inherent to mathematical modelling and experimentations, and provide educational (creativity, challenge, etc.) experience unique to problem-based learning. In this paper, we briefly introduce the aims and scope, organization and achievement of CUMCM. A selected contest problem from CUMCM-2004 is discussed. We also talk about some problems and difficulties currently faced by the contest.*

1. AIMS, SCOPE AND HISTORY

The China Undergraduate Mathematical Contest in Modelling (CUMCM) is a national annual contest in China for undergraduates. The aim of the contest is to give students exposure to the modelling process and to improve students' understanding of mathematics, mathematical modelling and experimentation, thereby providing an opportunity for the students to cultivate their creativity in problem solving and improve their ability.

In this three-day (72 hour) contest, teams of up to three undergraduates students will investigate, model, and submit a solution to, one of two modelling problems, which simulate real-word problems in engineering, management, etc. The contest begins at 8:00 a.m. on the third Friday in September and ends at 8:00 a.m. on Monday of the following week. During the contest, teams are permitted to reference any data source they wish, but they must cite all sources. Failure to credit a source will result in a team being disqualified from the competition. Team members may not seek help from, or discuss the problem with, their advisor or anyone else, except other members of the same team. That is to say, inputs of any form from anyone other than the team members are strictly forbidden.

In the USA, the Consortium for Mathematics and its Applications (COMAP) first organized the Mathematical Contest in Modelling (MCM) in 1985. The Interdisciplinary Contest in Modelling (ICM) was first organized in 1999. Teams

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from Chinese universities have participated in the contest every year since 1989, and recently more than half of the teams of MCM and ICM are from China.

Recognizing that the mathematical contest in modelling is beneficial to students and helpful to the mathematics education reform in universities, the China Society for Industrial and Applied Mathematics (CSIAM) organized CUMCM in 1992. CUMCM is co-organized by CSIAM and the Ministry of Education of China since 1994, and from 1999, the contest has been divided into two categories: Group A for four-year university students and, Group B for two-year college students. Because of the very challenging nature of the contest, it attracts the most competitive students in China in an ever-increasing numbers. Currently, CUMCM has become the most widespread extra curricular scientific activity for undergraduates in China.

Table 1. The statistics on Chinese students participating in MCM / ICM and CUMCM.

Year	MCM in USA		ICM in USA		CUMCM in China	
	No. of institution*	No. of teams*	No. of institution*	No. of teams*	No. of institutions	No. of teams
1989	3(143)	4(211)				
1990	4(158)	6(235)				
1991	10(161)	19(256)				
1992	13(189)	26(190)			74	314
1993	16(164)	38(259)			101	420
1994	33(192)	84(315)			196	867
1995	31(199)	84(320)			259	1234
1996	39(225)	115(393)			337	1683
1997	38(224)	107(409)			373	1874
1998	46(262)	138(472)			400	2103
1999	43(223)	155(479)	14(40)	23(60)	460	2657
2000	46(232)	169(495)	18(50)	29(70)	517	3210
2001	62(238)	198(496)	24(58)	38(83)	529	3887
2002	67(282)	216(525)	29(71)	54(106)	572	4448
2003	61(230)	204(492)	35(84)	83(146)	637	5406
2004	88(253)	297(600)	40(82)	101(143)	724	6881
2005	97(257)	389(644)	51(75)	125(164)	795	8492

Note: * The data are collected from http://www.comap.com. The bracketed numbers represent total participation by all institutions and teams.

In 2005, 8492 teams, from 795 institutions, participated in the contest. Almost all

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of the most prominent institutions, and nearly 50% of all institutions in China, were represented. It is also interesting that more than 80% of the participants are engineering, economics, management, and even humanities majors, other than the mathematics majors that one might expect. Table 1 gives the statistics on Chinese students participating in the contests MCM, ICM, and CUMCM. More details about CUMCM can be found in Li (2001), or from the website http://www.mcm.edu.cnT.

2. ORGANISING AND JUDGING SYSTEM

There is a CUMCM National Organizing Committee (NOC), which is setup by the Ministry of Education of China and CSIAM. In most of the provinces or regions in China, there is a CUMCM Local Organizing Committee (LOC). Currently, 27 of the total 34 provinces (or regions) in China have established their own LOC.

Teams register, obtain contest materials, and download the problems and data at the prescribed time through the CUMCM Web site. During the three-day contest, teams of Group A (B) can choose any one from the two contest problems of Group A (B). Each team should submit a solution paper to the corresponding LOC before the contest deadline. After the contest, LOCs start judging to rank the submissions by the contestants. The top 12% of all entries will be submitted to NOC for second round evaluation, and the others will also be ranked and perhaps, awarded prizes at the regional level. After the second round evaluation by NOC, only the top 3% of the total solution papers will be awarded the national-level first prize, and the figure for the 2nd prize is about 8%. Finally, about 15 outstanding papers will be selected and published in the journal *Engineering Mathematics*, which is one of the official journals of CSIAM.

3. THE CONTEST AND ITS INFLUENCE

Most students who register for the contest have some kind of training on how to participate in CUMCM from their mathematical modelling courses, from related mini-courses, or from seminars. Some students prepare for the contest independently through studying materials related to mathematical modelling. They can also get some guidance from their advisors before the contest.

Teachers are the key to the success of CUMCM. In order to properly prepare them, with university professors as advisors, in recent years NOC have cooperated with CSIAM and several universities to organize short-term training seminars. NOC also organizes a national conference CCTMMA (China Conference on the Teaching of Mathematical Modelling and Applications) every two years as an educational forum of exchange, where teachers share information, and discuss how to mentor the students effectively, and how to prepare and teach a high quality mathematical modelling course. These activities have had great impact on the mathematics education reform and have enhanced the teaching quality of courses related to the mathematics in most universities and colleges. The contest also encourages the publication of many innovative textbooks on mathematical modelling and mathematical experiments (Jiang, 1998).

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The contest is a real challenge to its participants and is much appreciated by the students. The special experience for students, provided by the contest, is very helpful in tapping their innovative potential and in strengthening their cooperative spirit. The contestants summarise their experience in one phrase “Once participated, lifelong benefit”. The whole contest process consists of three stages, namely, the training and preparation before the contest, the hard work during the three-day contest, and the summing up of students’ own experience and doing further work on the contest problems after the contest. Through these stages, students' creativity and overall ability are greatly improved. Indeed, most of the winners of CUMCM have done very well in their successive courses and projects before their graduation. The scientific and industry communities are getting to know more and more about CUMCM, and they are glad to accept the students who have the experience of the contest when they go to graduate schools or find jobs after their graduation. Some industry corporations, such as World-Sky Group, Netease Corporation and Higher Education Press, also sponsor the contest.

4. DIFFICULTIES AND PROSPECTS

CUMCM does encounter some difficulties as the participation continues to grow. The most important task facing NOC is about how to improve the whole quality of the contest. First of all, good contest problems are vital to the success of the contest. Contributing a good modelling problem, which is both a meaningful real-world problem, and which is also a solvable problem by most teams within three days, is a challenging task for the organizers.

Another difficulty the organizer faced is how to ensure the equity and fairness of the contest. Since the contest lasts for three days and it is essentially a completely open contest, it is not easy to ensure that teams do not violate the contest rules. As a matter of fact, some teams do violate them, for instance, by looking for help from teachers or other persons outside the team even on the internet. The organizer emphasizes the very importance of self-discipline. A firm policy is observed by NOC, namely, once we have the evidence of violating the contest rules by some teams, these teams will be disqualified from the competition.

5. AN EXAMPLE OF THE CONTEST PROBLEM

5.1. The Problem

The problem A from CUMCM-2004 is “Planning Temporary Mini Supermarkets for the Olympic Games”, which is summarized in the following.

The construction work of the Olympic Games 2008 in Beijing has been in planning and implementation processes. During the Olympic Games, temporary Mini Supermarkets will be built around the stadium for supplying food, souvenir and tourist commodities to the spectators, tourists and members of staff, each Mini Supermarket (MS) consisting of variety shops. For MS around the stadium, their location, size and the amount of sales should satisfy three basic requirements:

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demand for shopping, reasonable distribution and commercial profit during the Games.

The planning layout of the main stadiums for contest is shown in a figure (omitted here for saving space). For simplicity we only give, in Figure 1, the related parts and regions, such as streets (white denotes for pavement), bus and taxi stops, parking area, subway stations and restaurants etc., in which the areas marked with A1-A10, B1-B6 and C1-C4 denote the prescribed 20 shopping centres consisting of the MS.

One way to find the patterns of the consumer movement is to send out questionnaire forms to the spectators; they are the principal consumers during the preview games for investigating purchase demand and appetite of tour. Suppose that three games had been held in a stadium (Figure 2) and related data are collected and is shown in the Appendix (available at http://www.mcm.edu.cn).

Your team is asked to be a consultant for planning MS for the 20 shopping centres shown in Figure 1 according to the following steps:

- Based on the data of questionnaire given in the Appendix find features of the spectators' routes, meals and purchase etc.
- Suppose each spectator has two main routes each day. During the Olympic Games, one route to travel in and out the stadium and another route in going for a meal, and they always adopt the shortest route. Based on the result in 1 please calculate the distribution of consumer flux (in percent) in the 20 shopping centers in Figure 1.
- Suppose two different sizes of MS, large and small, can be chosen. Please plan the MS for the 20 shopping centres, i.e. the numbers of different MS in each centre such that three requirements are satisfied.
- Explain that your method is reasonable and the result is practicable.

Hints:

1. In commerce the "shopping loop" may be used to describe the covering area of shops. The main factor determining the choice of shop location is the buyer movement with their purchase demand in a shopping loop.
2. For simplicity assume that the National Stadium can admit about 100,000 spectators, the National Gymnasium about 60,000 and the National Swimming Center about 40,000, where each stand of the three buildings admits about 10,000. Assume also that each exit gate faces just one shopping centre and that all the shopping centres have the same area.

Appendix:

Send out questionnaire forms to the spectators three times with 33% reply, totally about 10,000 replies. Detailed data can be found in the attached access database, where the ages are divided into four groups: (1) less than 20, (2) 20-30, (3) 30-50 and (4) more than 50. We may design for four ways of travelling: by taxi, by bus, by subway and by car; three kinds of meals are provided: Chinese meal, Western-style

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food and in marketplace (fast food); and in six price ranges (except for meals): (1) 0-100, (2) 100-200, (3) 200-300, (4) 300-400, (5) 400-500 and (6) more than 500 (RMB).

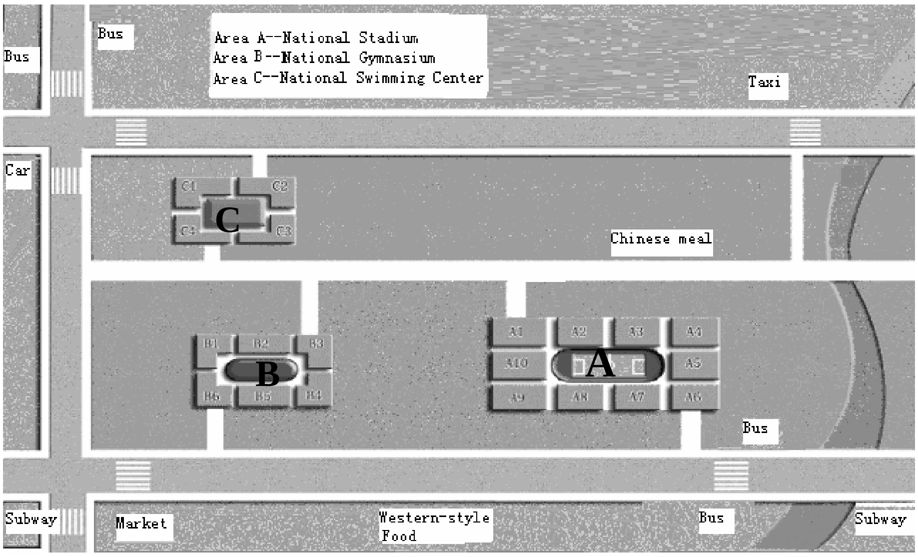

Figure 1. The planning layout of the main stadiums

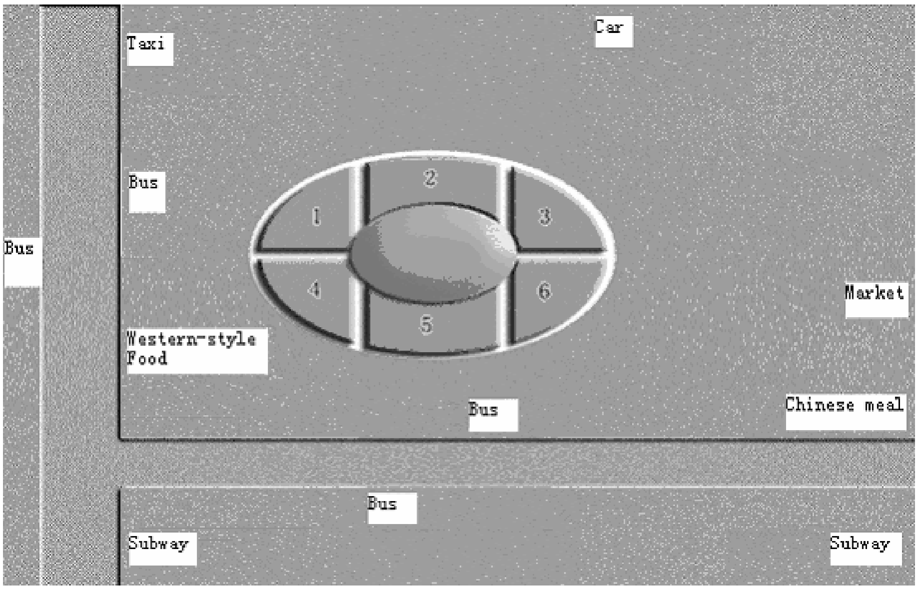

Figure 2. A Ready Stadium.

5.2. Comments on Students' Solutions

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The background of this problem is the requirement of the Olympic Games 2008 Beijing. The author of the problem has received help from Beijing Olympic Games Organization Committee, Beijing Municipal Administer Committee and Beijing City Planning Committee for the provision of the design assignment of temporary Mini Supermarkets (MS) and the stadium planning Figures.

This problem needs firstly to find features of the spectators in routes, meals and purchase preference etc. from the data of questionnaire. Students may use statistical methods or data mining to achieve this task. The related rules with the consumer movement should be discovered as enough as possible. For example, the patterns that people, of either sex and of different ages, may have different personal shopping preferences should be considered. Based on the given conditions that each spectator makes two journeys and they always adopt the shortest route, students can calculate the distribution of consumer movement in the 20 shopping centres. One of the approaches is to use a network flow model for calculation.

The designs for MS of the 20 shopping centres i.e. the numbers of different size MS in each center are the primary and pivotal parts of this problem. The keys are describing three basic requirements of shopping centers (demand for shopping, reasonable distribution and commercial profit) in mathematical terms. The demand for shopping can be decided by the distribution of consumer movement, but one fact, often ignored by students, is that demand for shopping must be considered according to whole building area not only a centre. The reasonable distribution means that the discrepancy of the numbers of MS in each centre is not too large. The problem gives no information about commercial profit, so students need to collect some data about cost, profit, etc. of MS with different sizes.

The designs for two sizes of MS of the 20 shopping centres satisfying three basic requirements are actually optimization problems. The keys of establishing an optimal model are mathematical formulations of decision variables, objective functions and restricted conditions. Clearly the decision variables are the numbers of two sizes of MS of the 20 shopping centres. Many students choose rationally commercial profit as the objective function and take demand for shopping, reasonable distribution as the restricted conditions. In general, such an optimal model is a linear or nonlinear integer programming which can be solved in principle by existing methods and software.

Some students separate this problem into three independent sub-problems**;** *each sub-problem aims only at one building*. They consider that the spectator in National Stadium would usually not go to shop in MS of National Swimming Centre. Such a separation way not only reduces the number of the decision variables resulting in a big simplification, but also even more accords with the actual situation.

It is worthwhile to notice that some students do not analyze the rationality of computing results. For example, some papers show that there are tens, or even hundreds, of MS in a centre. This is clearly incorrect in practice.

The modelling approach for this problem can also be used in many similar situations such as planning temporary mini supermarkets at big exhibitions, state fairs, huge temple fairs in China, amusement parks etc. Another characteristic of this

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contest problem is that it is very open. Various mathematical models and solving methods appear in students' solution papers. These include primary calculation, statistics, shortest path algorithms, network flow models, mathematical programming, circuit simulation method and data mining.

6. CONCLUSION

This paper gives a brief introduction to CUMCM, and a selected contest problem from the contest is discussed. According to our practice, the contest provides educational experiences unique to problem-based learning and teaching.

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