My Story with ICM

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Shanghai Jiao Tong University
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Overview


2012
Interdisciplinary Contest In Modeling
Certificate of Achievement
Be It Known That The Team Of
Xilun Chen
Hang Qiu
Chunzhi Yang
With Faculty Advisor
Zulin Sun
of
Shanghai Jiaotong University
Was Designated As
Outstanding Winner

Xilun Chen, Hang Qiu and Chunzhi Yang are senior undergraduate students in Shanghai Jiao Tong University. Xilun and Chunzhi major in Computer Science while Hang majors in Information Engineering. They first teamed up in May 2011 contending in the China Invitational Mathematical Contest of Modeling. They then participated in the China Undergraduate Mathematical Contest in Modeling (CUMCM) in September 2011 and won the first prize in Shanghai. In February 2012, they competed in the Interdisciplinary Contest of Modeling (ICM) winning the Outstanding Winner Award out of 1329 teams from all over the world. Currently Xilun is an intern in Microsoft Research Asia, Chunzhi is an intern in Microsoft Corporation Shanghai and Hang is an research assistant in Institute of Wireless Communication and Technology, Shanghai Jiao Tong University. They are all applying for further graduate education abroad at this moment.

Part I: Xilun Chen's Experience

Our experience on mathematical modeling contests was undoubtedly precious memory of mine, in which I had great times together with my teammates. I will never forget the times we spent together, when we were engrossed whole-heartedly in tackling complicated problems with meditation and brainstorming.

None of us would possibly imagine how far we have gone along the road of mathematical modeling contests when we first decided to participate in this contest. As I often bantered ourselves, we were nothing but an amateur team. The purpose of our participation in these contests was just for entertainment as well as a little bonus for scholarship nomination. We never had training, as we trained ourselves by contests. However, a contest that we never think about before or after it wasn't necessarily insignificant to us. In fact, we treat this experience as a treasure for our life.

It was on the Eastern China Mathematical Contest in Modeling that we three first became a team. At that time, Hang and Chunzhi didn't even know much about each other. Since they both had connections with me, I naturally became the team leader, a position I am usually not so interested in except for this time. At

that time, none of us had known even a little bit about the mathematical modeling. We chose a problem that required us to design a container satisfying some restrictions while maximizing its volume. We chose this since we had no idea for no problem, and this one seems straightforward to be solved. We treated as a high school homework problem for math or an assignment of Advanced Mathematics course. We should have named our paper as *We Just Ran Three Days of Mathematica* following *X.X. Sala-i-Martin* as he did in his paper *I Just Ran Two Million Regressions*, because the only thing we did was trying to solve an optimization problem with restrictions by Lagrangian Multipliers using Mathematica. In the three-day contest, the only thing we did was try to get output from our Mathematica, which turned out to give us a solution like this:

$$\begin{cases} \frac{r}{R} = \frac{1}{3}\left(-2 + \left(\frac{29}{2} - \frac{3\sqrt{93}}{2}\right)^{1/3} + \left(\frac{1}{2}\left(29 + 3\sqrt{93}\right)\right)^{1/3}\right) \\ \frac{h}{R} = 2 - 2\left(\frac{2}{3\left(-9+\sqrt{93}\right)}\right)^{1/3} + \left(\frac{2}{3}\right)^{2/3}\left(-9 + \sqrt{93}\right)^{1/3} \\ \frac{H}{R} = 1 - 2\left(\frac{2}{3\left(9+\sqrt{93}\right)}\right)^{1/3} + \left(\frac{2}{3}\right)^{2/3}\left(9 + \sqrt{93}\right)^{1/3} \end{cases}$$

We never know whether it was correct or not. Unsurprisingly, we wasn't designated any award. We got nothing but lessons, with the major one being that we knew that the contest was named as Mathematical Contest of Modeling, rather than Mathematical Contest of Solving Equations with Computer, which seemed stupid, but was crucial for us.

When we gathered again to compete in the China Undergraduate Mathematical Contest of Modeling (CUMCM), we knew at least that idea matters. This time I was so fortunate that there was a problem on graph theory, which I have been studying to some extent since I competed in Olympiad of Informatics Contest in high school.

One of the most essential tasks of this problem is to assign several squads of police to take control of a number of particular spots in the shortest time. It doesn't take much scrutiny to find out the nuance between this problem and the classical Bipartite Graph Matching problem by noting that bipartite matching minimizes the total weights of selected edges while this problem tries to minimize the maximum weight of selected edges. It was such a coincidence that I have pondered over exactly the same problem months before that contest and had come up with an effective and efficient method to solve this problem.

To my surprise, no one had addressed that problem before and no working algorithm was extant on the Internet to the best of my knowledge. (Perhaps people thought it too trivial to have a specific algorithm to deal with this problem.) Hence we got novelty, the key to succeed in MCM. Thanks to my teammates --- Chunzhi helped me on solving myriads of miscellaneous sub-tasks and Hang made a critical improvement to our approach of solving the last and most difficult sub-task.

Unfortunately, our model is too biased to Computer Science and away from traditional mathematics, which made our paper not fully digested and by the judges with no computer science backgrounds. This could explain how astonished I was during the paper defense when I found the discrepancy between what we deemed as highlights of our paper and what the judges believed as spotlights. We proudly explained to them that our method was not only polynomial-time but actually quite efficient and was scalable to large data, but they seemed to have no idea about algorithm complexity and show no interest in it. On the other

hand, they praised our work in several aspects that we never thought as noteworthy.

A first prize in Shanghai is much beyond our expectation beforehand, but also quite disappointing since the essential part of our work was not appreciated. What remained same with last time was that we kept learning lessons. Actually one of the most crucial reasons that we could succeed in MCM was that we summarized effectively and learnt lessons very fast.

If Eastern China Contest taught us about what was mathematical modeling, CUMCM taught us about what were important in mathematical modeling. We summed up a quantity of useful empirical tips that facilitated us greatly later in the ICM contest.

After these two events, we have accumulated some experience on MCM, although we had only working on it for six days. One or two days before ICM, we gathered together to study one or two previous papers designated as Outstanding. With all these experiences, we started to deem ourselves as veterans in MCM and were able to conduct a “thorough analysis” as commented by the judges.

ICM’s problem was also related to Graph Theory, in which we were responsible to uncover conspirators in an organization from their links of text messages of various labeled topics. We at first considered another discrete problem of MCM, but gave it up after some time since we believed that the problem has so ambiguous a statement that a stupid method would still work if we simply stick to the clearly specified criteria. Hence to avoid the scenario in the defense of our CUMCM paper that we had different understanding and emphasis of the problem, we chose the Graph Theory problem which we are more familiar with. This time I came up with an idea of a two-phase propagation approach enlightened by the Expectation Maximization algorithm that was another iterative two-phase method, which I happened to have read about right before ICM. We assign suspiciousness for both people and topics, and alternately and iteratively compute them in a graph-based model, hence forming the two-phase (P-phase and T-phase) propagation method.

We followed almost the same routine that I designed the program for the code algorithm, Chunzhi worked on peripheral sub-tasks and Hang also made an important fix to the method. This time I was not so confident about the novelty of our model as last time in CUMCM, but our experience enabled us to polish our model and paper better fitted for ICM contest. It was quite satisfactory that our model got a reviewer comment of “simple yet elegant”. This ICM experience made me believe that models are not a sufficient condition on its own to success in MCM/ICM contests. They, nevertheless, play an equally important role as paper writing, articulation, explication and polish of models. An extraordinary of either together with an above-average the other could almost guarantee your success. I guess maybe Hang’s improvement help take the step from Meritorious to Outstanding.

Although I have only been working on MCM for less than 10 days in total, it left me valuable memory and experience. No one will remember the awards we got after a short span, but there is something I treasured greatly, which is the immersion in solving a complex problem in a team. I used to enjoy this from OI programming contest except that we work individually. The rapture brought from the participation of ICM reinforced my determination to live a research-track life.

Also, our ICM experience gave me a chance to deliver a lecture on mathematical modeling, where I talked about our ICM paper and numerous practical tips and hints we summarized in CUMCM, which I attributed as our main reason to success that we were really good at summarizing and learning lessons. I had a great time when I felt that I could really help them on something.


Sharing My Experience to students in SJTU: http://news.sjtu.edu.cn/info/1010/113584.htm

At last, my brilliant teammates deserve my best encomium and may they embrace a bright future awaiting them. In All, I would like to convey my deepest appreciation to MCM/ICM contest for so many chromatic experiences.

Part II: Hang Qiu's Experience

My story about mathematical contest in modeling actually began in 2011 when my teammates and I first participated in Huadong Mathematical Contest in Modeling. It is a contest with smaller range, only inviting a few renowned universities in Eastern China. At the very beginning, we joined the contest for fun and honestly some extra bonus for scholarship competition.

Although with strong enthusiasm, we know little about mathematical modeling at that time. As sophomore undergraduate students, we are still used to the routine result-oriented problem solving approach in high school. Accordingly, we chose the problem which looked most like asking to calculate a result. Excavating mathematical knowledge that we had learned in the freshman year, such as Lagrange multiplier, we actually took pains to get a satisfactory result in the three days of contest. Without surprise, we yield no award in the end.

The result of this very first experience with mathematical contest in modeling didn't crash us down. In the opposite, we got a lot in active retrospect. After reading numerous other awarded team papers, we finally came to feel the essence of the contest. The result might not always be all that explains the teams' intellectual contribution. The process of getting it, like what kind of model the team use, with what algorithm the team approach to the problem, says it quite eloquently. Meanwhile, looking back at the three contest days, we found that our working efficiency was low. We worked with a serial schedule, when one had finished his work, the result was brought to the next teammate to go on with his work partition.

Taking these lessons, we participated into China Undergraduate Mathematical Contest in Modeling (CUMCM) later in September 2011. The topic we chose this time was about scheduling and resource allocation design for mobile police stations with certain city map. By exploiting our knowledge on graph theory and relevant algorithms, we went through all the sub-problems smoothly until the last and most difficult one: scheduling as quickly as possible to surround the criminal. Our algorithms for the first several sub-problems could only calculate if certain circle can be established on time. The ignorance of topology made the schedule act quite like a machine. Faced with this obstacle, the whole contest process was suspended. We calmed down, cleared our mind, and patiently scrutinized the details of our algorithms together. Realizing the ignorance of topology, I tried to add some intelligence control into the algorithm by defining the circle according to the topology, finding out the crossings where multiple roads intersect, and waiting there instead of further narrowing the circle. This modification largely shortened the surrounding time from 8 to 5 minutes. We were so surprised and excited when we check our result with other teams and found out that ours was the fastest schedule in our school. However, in the end, we only won a First-Prize in CUMCM, Shanghai. Though recommended us to national prizes, the administrator in Shanghai pointed out that our scheduling results shown in a graph are not clear enough. Maybe putting them in a table with specific number is more convincing. I still remember when we heard this comment, we were really angry at first. Because we were so confident and proud about our result, we thought it was a really bad excuse to not recommend our paper as highly as others. Until later reviewing our paper myself as spectator, I finally recognized that though the graph could show the result, it didn't provide comparable details. Judges might not be able to see the superiority of our approach. Similar as the last time, we conclude our contest together later, trying to find other lessons to learn. This time, we have a deeper feeling that the model and analysis, especially some shining points like creative thought, subtle design or even sensitivity analysis are all indispensable factors. What most impressed me was that, with a same topic, different teams can offer so many various approaches. Reading the awarded paper largely broadened my horizon.

After two contests, though there were ups and downs, we were actually trained and become a truly mature team. In February 2012, the contest administrator of Shanghai Jiao Tong University recommended us to participate in Mathematical and Interdisciplinary Contest in Modeling in USA. With great pleasure, we signed up and began another adventure on mathematical modeling. Faced with three problems, we audaciously took almost the first two out of five contest days to brainstorm every problem for possible approach. After a comprehensive comparison, we chose Problem C which we had deeper thought and was the best match with our background. The task was about analyzing potential crime conspiracy through over 400 text messages among 82 employees of a company. One of my teammates, Xilun Chen, was researching on Natural Language Processing, and I was conducting research on Wireless Communication and Networking. Moreover, the three of us like detective novel very much. As for me, I have read tens of books and movies about detective. I didn't know my teammates' situation, but judging from their similar enthusiasm just like me, I guess they are more or less the same. Quite naturally, we established a social network model. Recalling the knowledge on Lloyd-Max Quantization in course "Communication Principles", I proposed a two-phase probability-based iterative propagation algorithm, calculating topic and person suspiciousness from each other until convergence. With hard work and thorough analysis, we obtained beautiful and convincing result.

In these fruitful five days of contest, we proceeded with clear work partition and highly efficient teamwork. Learning the lessons last time, we carefully wrote the team paper, explaining the whole picture while focusing on every detail. Even at the last day before submission, we still worked together to polish our language, and check our grammar errors again and again. Due to the time difference between USA and China, the deadline was eight o'clock in the morning. We worked until midnight the last day. After five days of consistent highly concentrated hard work, to be honest, we were really exhausted that night. I remember that I still encouraged and insisted another proof reading at midnight though my teammates thought it was trivial and kind of resisted it. It was like the final sprint and we finally made it.

After submission, we didn't hear nothing until April, there are rumors that one team in Shanghai Jiao Tong University won one of the seven ICM Outstanding Winner. To be frank, we believed it so much that team was us. That kind of emotion was really complicated yet impressive for me. The emotion can be explained as self-confidence, truly expectation from the bottom of my heart, or even a bit anxious and worried, because, after endeavor in three contests, we want that recognition so badly. The most excitement didn't come when we confirmed our belief, it came when we read the comments from Judge Chris Arney and Judge Kate Coronges on UMAP Journal (Vol.33, No.3, Page 301) that our design was "creative and powerful".

Comparing with other teams in our school, we found that we were actually quite unique and different in many perspectives. One specific feature is that we are strongly against losing sleep in order to finish paper. While some teams stayed all night up to finish their paper during the contest, we maintained a normal sleep time. After two times of experience together, we were able to be highly synchronized, eating together while exchanging thoughts, sleeping at the same time, waking up the next day and meeting each other spontaneously around the same time as well. The teamwork was so smooth, efficient and productive. I enjoyed that so much.

Through mathematical contest in modeling, I not only got to know such great teammates, but also received much more. The contest is actually training for my further academic research in communication and networking. Mathematical model is the most common and necessary tool in my theory and practical research. The process of research is quite the same as it was in the contest, bringing out a creative thought, implementing it and testing it, and revising it again and again. "Research is search and search again." The contest has become a precious experience and lesson for my future research.

In an interview we accepted later from school reporters, my teammates expressed similar feeling. Xilun Chen has been researching in Natural Language Processing and Chunzhi Yang in Computer Vision. The contest also brings fresh things to their research. In that interview, we shared about some experience and lessons to our schoolmates and hope they could be of a little help to different life tracks.

The award also gave me an extra bonus and helped me to get my third National Scholarship, the highest scholarship offered in my school. It may be a perfect end of our undergraduate contest experience, but it is also a fresh new start for our graduate study and future research. I extend my greatest appreciation to my teammates and wish us a great future in each other's research field. Thanks again to MCM&ICM for the award, and more importantly, thanks for providing such an opportunity for me to add a colorful chapter to

my life.

Part III: Chunzhi Yang's Experience

In the spring of 2011, in algorithm and complexity class Xilun was sitting next to me. He asked if I wanted to participate in East China Mathematical Contest in Modeling. I thought it was a good chance to gain some awards in the university and hone knowledge about mathematics and modeling. Some days later, Hang found Xilun and said he wanted to participate in the contest too. In this way, Xilun, Hang and I composed our modeling contest team and this was the beginning of my story with the ICM. Xilun and I major in computer science and Hang majors in electronic engineering. Our three team members all have fundamental mathematic knowledge and programming skills.

East China Mathematical Contest in Modeling was the first time of all our three team members to participate in such context. Our only experience and knowledge is from courses in university. As we received the problem, we tried our best to find solution with strong enthusiasm. Although we got very precise result, we solved this problem only as a normal mathematical problem and we did not get good awards. When informed the result, we were disappointed and confused about the reason why our totally correct answer could not win the first prize. We concluded the reason was we focused on the result too much without meditation and exploration on modeling.

After this contest we focused on our course in school. Actually, we did not have much time to prepare for those contests. Fortunately, there are many mathematic and algorithm courses in our curriculum. This does not mean we did not treat contests in modeling seriously. You can find our attitude towards contest from this. We regard those contests as an opportunity to use and enhance our knowledge about mathematics and modeling and to gain honors meanwhile. Certainly, we studied some algorithms and read some papers during the process of contest. However, we do not train for those contest specially or chase awards too much. What we focused on is the process of participation into those contest rather than the results. Moreover, I think the topics of those contests in modeling are very challenging and interesting.

The second opportunity for us to participate in a modeling contest came several months later. We participated in China Undergraduate Contest in Modeling in September 2011. This time We were more concentrated on modeling rather than the result. There were three problems and we chose the problem about graph theory, since Xilun and I both have some knowledge and coding skills about it. The problem gives a map of some city with roads, intersections and position of traffic police patrol station. It assumes that police force of one station can only blockade one intersection. The first requirement is to give range of each station’s jurisdiction in order to ensure that wherever a criminal case happens the police can reach in 3 min. We used a greedy algorithm to solve this problem, that is, we assign an intersection to a station which can reach in 3 min with least work load and for those intersections which has no station reachable in 3 min, we just assign them to the nearest station.

The second question is to reassign the police force of all the stations in a district to realize fast blockade of 13 main streets. We designed a model for this question which intersections and stations are represented by nodes and roads are represented by edges. What we are required to do is to find a mapping between stations and intersections which can ensure the maximum time that the police of each station reach the correspondence intersection is shortest. We established a bipartite graph of which one part is stations and the other part is intersections to be blockaded and the edges are the cost time between stations and intersections. Based on previous algorithm about bipartite graph match, we proposed a modified algorithm which can find a mapping of bipartite graph which longest edge is minimum. We first sort the edges from long to short. Second, we delete the longest edge in this graph and use Hungarian algorithm to find if there is a perfect matching in this graph. If there exists a perfect matching, we go back to the second step. If there does not exist such matching, the last deleted edge is just the result.

Another question is the case occurred at one intersection in this city and we were required to find a scheduling scheme to blockade the region where criminals could reach in the shortest time. This question is really interesting with practical significance. We divided the task into two phases intuitively. The first phase is to find the region that criminals could reach in a certain time. The second phase is to find whether police can blockade this region in time. The second phase is very similar to the second question, so we focused on the first phase. We adopted the algorithm which expands the region partially in a time. If the police cannot blockade the region in time, we expand this region to police direction only at nodes which police cannot reach in time. The experiment result is excellent: we can blockade the whole region in only 5 min.

By writing the process of contest in detail, I want to transfer my understanding about mathematic modeling. All the problems of contests have real background. The process of modeling is to abstract those real and literally descriptive problems into mathematical problems that can be solved by using some mathematical techniques or algorithms. We need to find a proper way to describe those affairs in real life in mathematical way rationally. Moreover, we need to ensure that the mathematical problem is solvable at the same time. In this way, we can see the extreme importance of modeling in process of solving real-world problems.

In both natural and social science, we can find the use of modeling so widely and important. As my major is computer science, I always have to use programming to solve some problems and I need to establish a model which can be described by program. Moreover, some of the core problems in computer science must be solved using mathematical methods and in this process we must abstract the computer science problems into mathematical model. In this sense, we may use mathematical modeling all the time as we solve physical problems, chemical problems and so on.

Of course, participation in contest needs really hard work and diligence. We worked in Hang's quarters for four day time without any rest. However, our well-designed model and algorithm did not win the favor of judges. They said our model needed more creative idea and some shining points. Also, we added too much graphs in the paper and insufficient table of data.

In February 2012, we participated in Mathematical and Interdisciplinary Contest in Modeling in USA. Similarly with before, the first step is brain storm. We read all the problems and tried to find out some initial thoughts and which problem is more suitable for us. Learning from the experience before, we chose problem C which we are more familiar with. We were given a group of suspected conspirators who form a

communication network by sending messages of various topics to each other. Some of the given people are known to be involved in the conspiracy while some others innocent. We are required to identify the most probable conspirators among the remaining ones. At the first glance, this problem is similar to have some relationship with natural language processing which is Xilun's research topic. The first idea came to my mind was that this problem can be solved by using some machine learning methods. We can use those given conspirators as training data and use some features to find the remaining conspirators. However, based on our experience, this solution is far from the purpose of modeling contest and cannot win any awards. There is no modeling process in this method.

From our previous understanding of modeling, we tried to understand the nature of this problem and establish a mathematical model which can describe the problem properly. Based on this idea, we proposed an important assumption that the suspiciousness of a person is decided by both the people with whom he talks and the topics he talks about. This is the first assumption of those assumptions written in our paper. Although this assumption is quite simple and intuitive, but nature of things is always so elegant and simple.

From this idea, we proposed our model. We assume the likelihood of being involved in conspiracy propagate through this communication network. We assign each person (i.e. a node in message network) a real number to represent the likelihood of being involved in conspiracy. This number will be updated during the iterative propagation process. We also assign a real number to each topic to indicate how probable this topic is involved in the conspiracy. This number is not fixed and will also be iteratively modified during the propagation. We do several iterations of the following 2-phase propagation process until convergence. Each iteration consists of the following two phases: *Person Phase*, in which we recalculate the suspiciousness of each node, based on the suspiciousness of its neighbors and messages between it and its neighbors; and *Topic Phase*, In which we recalculate the suspiciousness of each topic, based on the suspiciousness of people who talk about this topic. We also exploit an exponential decay between two iterations to make the effect of messages attenuate as the distance increase.

In the four day time, we designed our model and algorithm, conducted experiments and finished our final paper. We devoted our full energy and cooperated quite well. I think one important reason for us to win outstanding winner is that we had a clear division of labor and could discuss with each other efficiently.

As I said in an interview to us later, I found the process of participating into the ICM is quite similar to real academic research. We chose a topic, analyzed the problem, designed model and algorithm, conducted experiments and finished our paper. In this way, I think this experience will be very helpful for us in future research work. This competition also taught me that research requires working and reworking experiments, revising algorithms and an indomitable spirit to pursue perfection. Just as one of my faculty advisor said research sometimes means searching the better answer again and again. As all of our team members will pursue further study in each one's field in America and we are now busy with application, this award will certainly enrich our experience in academia and have positive effect on our application.

Another great treasure gained from this experience is my outstanding and excellent teammates. I just enjoy discussion and teamwork with them. They are so creative and motivated. I'm sure this experience of teamwork will benefit me in future career.

Finally, thanks to MCM&ICM for this award and such a wonderful and unique experience.