Transcript of talk given at IIM Calcutta on 24 January 2017

1. kemonachen? Bhalo Achee? Suprabhat to all of you!

2. I want to thank Prof. Nag for inviting me, and more importantly for contributing 3 very challenging applications of optimum decision making to the recent graduate textbook that I edited. For details about this book see:
http://www.springer.com/in/book/9781493910069

3. First allow me to share some thoughts: As Indians, we should all feel very proud of India's recent scientific ahievements.

(i) Few years back, ISRO successfully launched the Mars orbiter 'Mangalyan' at a cost of only 70 milion $, far lower than what other countries take for such a task, Now `Agni' missile, and so on ….

(ii) My cousing brother P. Subrahmanyam at Defense Science Lab successfully developed the light combat aircraft `Tejas' using only indigenous components.

Etc.

(iii) But one important goal still eludes. Sadly India's population still growing rapidly. I earnestly seek help of young prople like you to stabilize India's population, in fact the whole world's human population, at least now, by convincing people of all religions and races of its urgent need.

4. My area of research and applications is ``Optimum Decision Making''. I want to convince all students here, that a position involving ``Optimum decision making'' is an excellent career goal.

A question for you. When you want to praise something, what do you compare it with? In classical Indian Literature, they would compare it with ``Mount Everest'' or the ``Mighty Ocean''.

When you want to praise something as ``very good'', what do you compare it with? In classical Indian literature, they would say it is like ``ksheerasagar'' or ``milk ocean'' or ``mighty ocean of milk goodness''. In applicability, challenge, elegance, and depth ``Optimum decision making'' is much like ``Ksheerasagar''.

I strongly encourage all students here to learn optimum decision making techniques well. Subject is also called by several other names, Management science, Scientific decion making, Operations research or OR, Analytics, Systems engineering, etc.

``Optimum decision making'' provides Executives a quantitative and rational basis for making important decisions.

5: Ancient origins : The ``urge to optimize'' seems innate in not only humans, but also animals. More than 100000 years ago humans living in mountain caves used ``shortest paths'' to fetch water for their living from the nearby river. Migratory animal herds used ``shortest paths'' for seasonal migrations.

Find shortest path from cave home to river

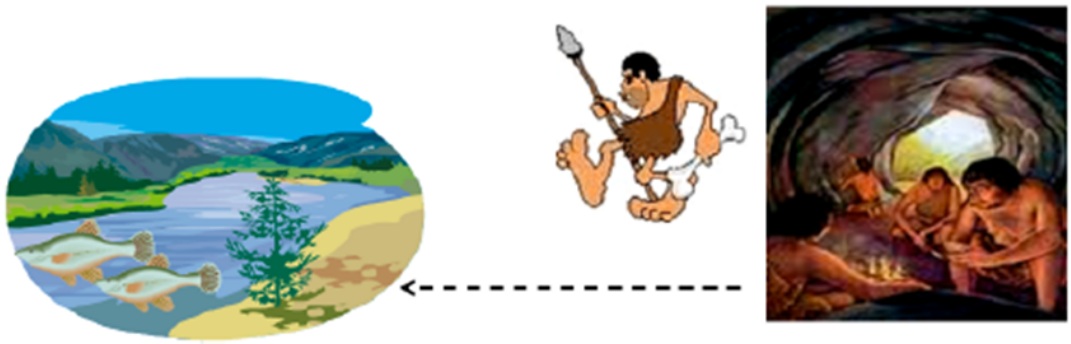

Figure 1: An unconstrained minimization problem

Find the shortest path from cave home to river, avoiding the area occupied by tigers!

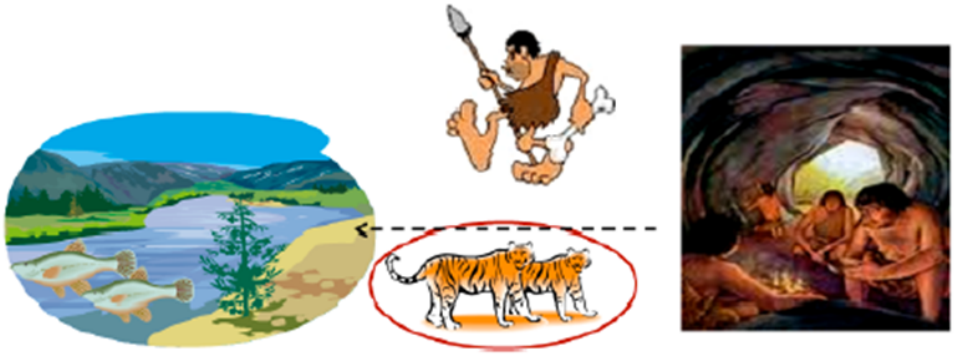

Figure 2: A constrained minimization problem

The mathematical work of Newton, Bernoulli, Leibniz, Lagrange in 17^{th}, 18^{th} centuries on characterizing local minimums and maximums of differentiable functions is an important part of this subject, even though the subject was not recognized at that time.

6. Beginnings under the name ``Operations Research (OR)'': At that time, A. P. Rowe of British Royal Air Force formed a team to analyse operations at control room of British Radar Station with goal of reducing number of artillery rounds to shoot down an intruding enemy aircraft. They formed the techniques under the name ``Operational Research''. When the subject reached the USA, the Americans changed the name to ``Operations Research (OR)''.

The first industry to adopt OR is the Petrochemical industry to improve performance of plants. Now OR techniques play very significant role for decision making in many industries and service organizations. The approach consists of following steps:

(a): Identify all process parameters which affect performance, their values are called ``decision variables''. For example in a chemical plant making chemicals, these can be temperature of reactor, concentrations of various ingredients in input into reactor, reaction time, etc.

(b): Construct a mathematical model for system operation and optimization. Develop measures of effectiveness of system performance, constraints that system operation must satisfy, all in terms of decision variables.

(c): Solve the model using an efficient algorithm, and implement optimum solution obtained.

7. Algorithmic developments on OR: A significant algorithmic development in OR is the ``Simplex method'' for LP (Linear Programming models) by George Dantzig in 1947.

But in the beginning, several influential people downplayed its importance. When I took the LP course from Dantzig at University of California, Berkeley he told us the story that when he gave a talk on the simplex method at an important OR conference, the highly influential Prof.Hoteling in the audience commented ``Mr. Dantzig, you showed your algorithm for minimizing a linear function subject to linear constraints. But what good is it, almost everything in the world is nonlinear!!!'', and everyone in audience clapped vigorously. But fortunately, the well respected mathematician Von Neuman came to Dantzig's defense and predicted that in near future simplex method will attract many applications.

Dantzig mentioned that this Hoteling was a very fat gentleman who loved to swim in the ocean, and the talk is that when he swims, the level of the ocean raises significantly. I drew the following cartoons to show it.

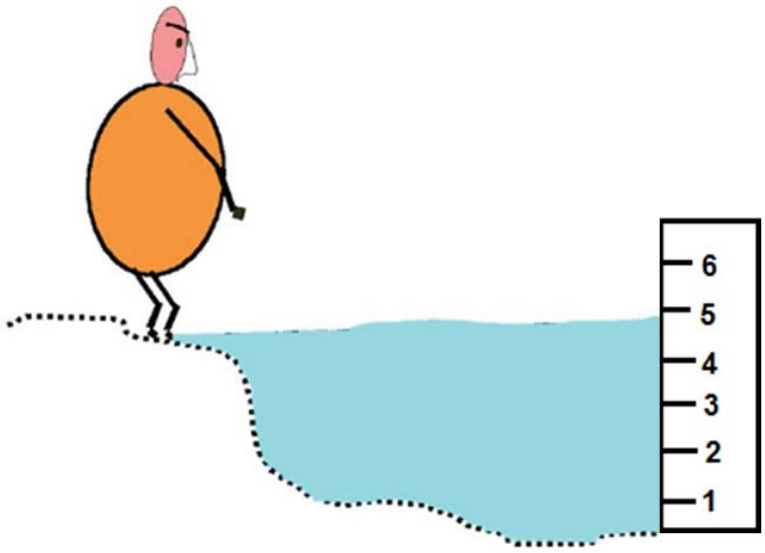

Figure 3: Hotelling (a whale of a man) getting ready to swim in the ocean

Figure 4: Hotelling swimming in the ocean. Watch the level of the ocean go up

8. My first Introduction to OR:

In the 1950s I was an employee in the SQC & OR Division of the Indian Statistical Institute (ISI) in Kolkata, and also a graduate student searching for a thesis topic in Statistics. The Director at that time was Dr. C R Rao, he promoted the study of Statistics vigorously.

We used to get many foreign visitors at ISI giving lectures on new developments. One year a young Mathematics Professor from the USA visited and delivered a series of lectures on a new subject “Operations Research (OR)” being developed at that time. In his first lecture he mentioned a problem “Traveling Salesman Problem (TSP)” saying that

the problem is very easy to explain, but nobody knows how to solve it yet. I became very fascinated by it, and on the spot decided to work on it, and switched my research area from Statistics to OR.

Subsequently, whenever my relatives asked me what I was doing, I used to tell them that I was studying “Operations Research”. They used to say “what is that, we never heard about it”. The subject was unknown in India at that time.

This visitor came with his young wife who was a stunning beauty, also very sociable and talkative. She became the centre of attraction for all the male students like me at ISI. Whenever she showed up on campus, there used to be a throng of male students around her. She used to come to campus along with her husband and attend all his lectures. But she never seems to have paid any attention to his talks, she would sit in a back bench and immerse herself in knitting. All of us boys in class used to turn our heads back frequently to peek at her beauty.

The hostel in ISI where I lived was in a building adjacent to the main campus building. One morning as I was getting ready in my room to go to campus, a messenger came and told me that the Director wants to see me right away. In Indian colleges, a thing like this normally occurs only when the student has done some mischief and the Director calls to discipline them. So, I became afraid that may be the American Visitor's wife complained to the Director about my constant staring at her.

With this fear in mind, I approached the Director's office. The door was partly open, and I could see the visitor's wife sitting in a chair talking with the Director whose face was hidden by the door. I knocked expecting the worst, and opened the door widely. To my great relief, the Director greeted me “Murty please come in, we have been waiting for you. I am sure you have met the American visitor's wife. She is planning to go sight seeing in the city today. Can you accompany her and show her all the interesting places in our city like the Kali Maata Temple, Victoria Memorial, etc.?”

I agreed and we started right away in the Institute's car. On the way she asked “Mr.Murty, what are you studying?”. I replied that I was studying Operations Research, expecting that as the visiting professor's wife she would know what it is.

After spending the whole day sightseeing, we were returning to ISI along Chittaranjan Avenue. On the left there was a huge complex of well lighted buildings, she asked what that is, then we had the following conversation:

“Maam that is the famous Calcutta General Hospital, the largest hospital in Asia at this time with over 1100 beds.”

“Murty, you must be spending a lot of time there!”

“Maam, why do you think so? I am quite healthy.”

“No, I did not mean that way. I thought you are doing research on Operations!!”

Then I explained to her that I am only trying to do research in her Husband’s subject “Operations research” , and not working on surgeries, and we both had a good laugh.

9. Fortunately for me, in 1960 USA established the USEFI (US Educational Foundation in India) who started giving travel grants for one year study at an American University to selected Indian students. With the encouragement of my Department Head Mr. S. C.Sen, I got this travel grant, and with ISI providing money for living expenses, I left in 1961 for a year's study of OR at the Case Institute of Technology in Cleveland, Ohio. There in the first term itself I got exposed to linear programming (LP), Hungarian method for the

assignment problem (which is a relaxation of the TSP I was studying), nonlinear programming (NLP), and other OR subjects.

I needed a computer code for the Hungarian method for my research on the TSP, and a classmate, Caroline Karel, wrote the code quickly and gave it to me to use. With that I developed an algorithm for ranking the assignments in increasing order of cost, and quickly modified it into the Branch and Bound (B&B) method for TSP, and tested it. We showed the results to an Assistant Professor at Case Institute at that time, who told me to write it as a technical report, and I had my first paper in OR (you can see this on my webpage). He was moving to MIT shortly, and he told me that he will get this algorithm tested there on large scale problems, and then submit it for publication.

At the Case Institute I learnt about the reputation of George Dantzig, then teaching at the University of California, Berkeley (UCB). Enclosing my technical report, I wrote to George Dantzig expressing my desire to pursue my graduate studies for a Ph. D. at UCB.He offered me an RA position, and in Fall 1965 I joined the graduate program at UCB.

When I met my advisor at Berkeley, David Gale, for the first time, he asked me “Mr. Murty, what do you want to work on?”. I told him “Prof. Gale, I want to work on optimization”. Thinking about this today, I am so happy that I replied in this way at that time, as optimization has opened many opportunities for me. I also want to encourage young scholars planning their careers to seriously consider optimization (Optimum Decision Making).

After getting my Ph.D., in Fall 1968 I joined the IOE faculty at UM as an Assistant Professor. Since then I had the opportunity to work on applications of optimum decision making in many different areas of application (container terminals in ports, airports, variety of manufacturing and service industries, warehouses, army , etc.).

Please see my webpage for reports on some of these challenging applications. Also, the recent Springer textbook on Case studies in OR: Applications of Optimum Decision Making (see http://link.springer.com/book/10.1007

Developing a DSS (Decision Support System) for daily operations inside a container terminal: Work carried out at HIT (Hong Kong International Terminals), a Container Terminal in Hong Kong Port.

The service quality of a container terminal is measured by the “Vessel Turnaround Time” (the average time the terminal takes to process a docked vessel (i.e., unloading all the ICs (import containers) from the vessel, and loading all the ECs (export containers) into the vessel), which is directly in influenced by the GCR (Gross Crane Rate; the number of ICs unloaded from, and ECs loaded into the docked vessel per hour of QC (Quay (or Shore) Crane time), which itself is influenced by the congestion that ITs (Internal Trucks that carry containers between the shore and the SY (storage yard)) encounter in their movements between the shore and the SY. When we started the work, they had the policy of allocating a separate set of ITs to attend to each QC working on the shore. We showed that all quality metrics can be improved by following a “pooling policy” that maintains all ITs in a single pool and dispatching them to the QCs as needed; and using a DSS developed for allocating storage spaces in the SY to arriving containers. These policies were subsequently implemented by all major Container terminals in the world.

Some other challenging applications are: Designing dams optimally, in Freight railroad industry to form goods trains optimally, sequencing surgeries to be performed by a surgeon in a day optimally, etc. Please see the Case studies Book,

10. The story of the banyan tree in Ann Arbor:

I was born in a small village called “Pandillapalli” after the Village Goddess named “Pandillamma”, in the State “Seemandhra” in India. The village used to have many massive Banyan trees, with large aerial root systems. During my childhood in the 1940s I and my childhood friends used to play under the shade of these trees, and enjoy watching the birds living on these trees, eating the many banyan fruit that the trees used to yield.

After I joined the IOE Department in the University of Michigan, Ann Arbor (UM) as a faculty member in 1968, we bought a house on Alton Court in Ann Arbor. My neighbour there was a faculty member in the Botany Department at UM, and the Director of the UM Botanical Gardens and the beautiful greenhouse containing many tropical plants there.

I am a lover of nature and trees, and had many discussions with my neighbour on the tree species I could grow on my lot. One year I brought some banyan tree seeds from my village Pandillapalli, and planted them in a pot. One seed germinated, and I was growing that banyan seedling as a house plant.

It started growing nicely, but by that time I had been travelling quite a bit to several foreign universities, and it was becoming difficult to find friends who would take care of it when we are away from Ann Arbor. One summer day, my neighbour saw that plant and asked me what it was. I explained to him that it is a banyan tree that I was growing from seed brought from my village in India. Then he asked me whether I could donate it to the UM Botanical garden so that he could plant it in the greenhouse. I agreed and gave the plant to him.
He transplanted that banyan tree seedling in the greenhouse. It has been growing well there, and now it has grown into a medium sized banyan tree with several aerial roots, and has become the centre of attraction inside the green house. If you have plans to visit Ann Arbor, make sure to visit the green house in the UM Botanical garden and see this banyan tree.

11: My current work: Currently visiting KFUPM in Dhahran, Saudi Arabia, and working with Aramco on applications of clustering models in developing an offshore oil field 60 miles off the Eastern coast of Saudi Arabia.

Input data for a clustering problem is data on a set of objects. Desired output is a partition of set of objects into disjoint groups (clusters), and find a ``Centre'' for each cluster, to minimize some objective function. In our application there are 90 target locations where wells have to be drilled in a 15 X 8 mile area field.
Need to partition this set into clusters with 6 to 10 target locations to be drilled, and find the centre of each cluster where a jack up rig will be located to drill them.
Daily working rate for a rig can be between 150000 to 200000 $/day, and it may take upto 300 days to drill a well. Very high costs, very challenging problem.

12: I want to encourage all young scholars here, to seriously consider learning optimization techniques well and pursue optimum decision making as a career option.

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