# OPERATIONS RESEARCH

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# BOOKS

1. **An Introduction to Management Science –Quantitative Approaches to Decision Making, David Anderson, Dennis J. Sweeney, Thomas A. Williams, West Publishing**
2. **Operations Research-Applications and Algorithms, Wayne Winston, Thomson, Brooks/Cole**
3. **Operations Research: An Introduction Hamdy A. Taha**
4. **Applied Management Science-A computer Integrated Approach for Decision Making, John A. Lawrence, Barry A. Pasternack, John Wiley.**
5. **Applied Mathematical Programming Using Algebraic Systems, Bruce Mc Carl. Thomas H. Spreen -Electronic Book**
6. **Linear Programming for Managerial Decisions, Ahmet Acar, METU.**
7. **Linear programming and Network Flows, Makhtar S.Bazaraa, John J. Jarvis, Hanif D. Sherali, Wiley**
8. **Network Optimization: Continuous and Discrete Models, Dimitri P. Bertsekas http://www.athenasc.com**

**Applied Management Science : Making Good Strategic Decisions Hussein Arsham**

**http://ubmail.ubald.edu/~~harsham/opre640/opre640.html**

# Business and Management Science

- **Every enterprise has an objective it wishes to accomplish.**
- **Companies that operate for profit want to provide products or services to customers in order to make money for their owners or stockholders.**
- **A nonprofit organization such as a hospital may want to provide services to patients at minimum cost.**
- **In general, the goal of both <u>for-profit and not-for-profit</u> organizations is to optimize the use of available RESOURCES, given all the internal and external constraints placed them.**
- **Success is usually measured by how well they do so.**

**Thus, an organization is always looking for ways to run**

- **More efficiently,**
- **More effectively,**
- **More profitably.**

# WHAT IS MANAGEMENT SCIENCE?

- ***Modern-day management science grew out of successful applications of the scientific approach to solving military operational problems during World War II.***
- ***Hence it was originally dubbed "operational research"***
- ***After the War as this approach found its into all areas of the military, government, and industry the term was shortened to "operations research" (OR)*** ***.***
- ***As managers in business began using operations research approaches to aid in decision making the term "management science" (MS) was coined.***
- ***Today there is a little distinction between the terms, and they are used interchangeably in the literature.***

- ***OR/MS IS A DISCIPLINE THAT ADOPTS THE SCIENTIFIC APPROACH FOR PROBLEM SOLVING TO DECISION MAKING.***

- ***THE USE OF LOGIC AND MATHEMATICS IN SUCH A WAY AS TO NOT INTERFERE WITH COMMON SENSE.***

# MS/OR IS THE SCIENTIFIC APPROACH TO EXECUTIVE DECISION MAKING, WHICH CONSIST OF

1. **The art of mathematical modeling of complex situations**
2. **The science of the development of solution techniques used to solve these models**
3. **The ability to effectively communicate the results to the decision maker.**

# MS/OR Time Line

**1665 Newton's Method for Finding a Minimum Solution of a Function, I. Newton**

**1736 Königsberg Bridge Problem, L. Euler**

**1738 St. Petersburg Problem, D. Bernoulli**

**1763 Bayes' Rule, T. Bayes**

**1788 Lagrangian multipliers, *Mécanique Analytique*, J. L. Lagrange**

**1795 Method of Least Squares, C. F. Gauss, A. Legendre**

**1823 Solution of Inequalities, J. Fourier**

**1823 Principle of Utility, J. Bentham**

**1824 Kriegspiel (war gaming), von Reisswitz**

**1826 Solution of Linear Equations, C. F. Gauss**

**1833 Analytical Engine, C. Babbage**

**1873 Solution of Equations in Nonnegative Variables, P. Gordon**

**1880 Markov Chains, A. Markov**

**1896 Pareto Optimal/Efficient Solution, V. Pareto**

**1896 Solution of Linear Equations as a Combination of Extreme Point Solutions,**

**H. Minkowski**

**1900 Time Studies/Scientific Management, F. Taylor**

**1900 Gantt Charts, H. Gantt, F. Taylor**

**1903 Solution of Inequality Systems, J. Farkas**

**1909 "The Theory of Probabilities and Telephone Conversations," A. K. Erlang**

**1913 Inventory Economic Order Quantity (EOQ), F. W. Harris**

**1914 Lanchester's Equations, F. W. Lanchester**

**1915 Positive Solution to Linear Equations, E. Stiemke**

**1927 "Application of the Theory of Probability to Telephone Trucking Problems,"**

**E. C. Molina**

**1928 *Probability Theory and Its Engineering Uses*, T. C. Fry**

**1930 Econometric Society founded**

**1931 Quality Control Charts, W. Shewart**

**1933 Hypothesis Testing, J. Neyman, E. Pearson**

**1936 Transposition Theorem, Linear Inequalities, T. Motzkin**

**1936 Facility Location, E. Weiszfeld aka A.Vazsonyi**

**1937 Time Zero: British military applications – the term Operational Research first used**

**1939 "Mathematical Methods of Organization and Production," L. Kantorovich**

**1939 Optimality Condition for Constrained Problems (Master's thesis, U. Chicago),**

**W. Karush**

**1941 *The Structure of the American Economy* (Inter-industry Economics), W. W. Leontief**

**1941 Transportation Problem, F. Hitchcock**

**1942 USAF military OR**

**1942 Antisubmarine Warfare Operations Research Group (first U.S. civilian group engaged in**

**military OR)**

**1942 UK Naval Operational Research, P. Blackett**

**1942 Search Theory, P. Morse, R. Rinehart, B. Koopman, G. Kimball**

**1943 Neural Networks, W. McCulloch, W. Pitts**

**1944 *Theory of Games and Economic Behavior*, J. von Neumann, O. Morgenstern**

**1944 Utility Theory, J. von Neumann, O. Morgenstern**

**1944 Exponential Smoothing, R. Brown**

**1945 Project RAND (Douglas Aircraft Co.)**

**1945 USN Operations Evaluation Group (OEG)**

**1945 "The Cost of Subsistence" (Diet Problem), G. Stigler**

**1946 "Methods of Operations Research" [OEG Report (Classified)], P. M. Morse, G. E. Kimball**

**1947 Linear Programming Model, G. B. Dantzig**

**1947 Simplex Method, G. B. Dantzig**

**1947 Project SCOOP (USAF Scientific Computation of Optimal Programs)**

**1947 *Theory of Games and Economic Behavior*, 2nd edition, J. von Neumann, O. Morgenstern**

**1948 The RAND Corporation**

**1948 Johns Hopkins US Army Operations Research Office (ORO)**

**1948 First courses in OR at MIT**

**1948 Operational Research Club of Great Britain**

**1949 Monte Carlo Simulation, S. M. Ulam, J. von Neumann**

**1949 "Programming of Inter-Dependent Activities I, General Discussion," M. Wood, G. Dantzig.**

**1949 "Programming of Inter-Dependent Activities II, Mathematical Model," G. Dantzig**

**1949 *Dynamic Equipment Policy*, G. Terborgh**

**1949 Cowles Commission Conference on "Activity Analysis of Production and Allocation"**

**1950 Quality Control, W. E. Deming**

**1950 *Operational Research Quarterly*, first OR journal, now the *Journal of Operational Research***

**1950 Nash Equilibrium, J. Nash**

**1950 Simulation/War Games**

**1950 Decision Analysis, W. Edwards, R. Luce, H. Raiffa, R. Howard, R. Keeney**

**1950 Navy Operations Evaluation Group (OEG)**

**1950 Military Gaming**

**1950 *An Introduction to Probability Theory and Its Applications*, vol. I, W. Feller**

**1950 Dynamic Programming, R. Bellman**

**1950 Shortest Path Problem**

**1950 OR in Industrial Sector: British Iron and Steel Industry Research Association, C. Goodeve;**

**British National Coal Board, P. Rivett**

**1950 First Solution of the Transportation Problem on a Computer, SEAC, National Bureau of**

**Standards**

**1951 Unclassified version of *Methods of Operations Research*, P. M. Morse, G. E. Kimball**

**1951 First computer-based simplex algorithm, SEAC, National Bureau of Standards**

**1951 First Symposium on "Linear Inequalities and Programming"**

**1951 *Activity Analysis of Production and Allocation*, Koopmans, T. C. (ed.)**

**1951 *The Structure of the American Economy*, (Inter-industry Economics) W. Leontief**

**1951 "Nonlinear Programming," (optimality condition for constrained problems), H. Kuhn, A.**

**Tucker**

**1951 "Maximization of a Linear Function of Variables Subject to Linear Inequalities," (Simplex**

**Method), G. Dantzig**

**1951 "Some Problems in the Theory of Queues," D. Kendall**

**1951 Naval Post Graduate School OR program**

**1951 "Study of Negro Manpower in Army," Johns Hopkins Operations Research Office**

**1951 Primal-dual Linear Programs, J. von Neumann, G. Dantzig, A. Tucker**

**1951 OR group established at Courtland (UK fiber producer)**

**1951 "Application of the Simplex Method to a Transportation Problem," G. Dantzig**

**1951 "A Proof of the Equivalence of the Programming Problem and the Game Problem," G. Dantzig**

**1952 *Operations Research*, First OR journal in the United States**

**1952 Operations Research Society of America (ORSA) founded**

**1952 Portfolio Analysis, H. Markowitz**

**1952 First OR Application in Agriculture, C. Thornthwaite**

**1952 First degree program (MA and Ph.D.) formed at Case Institute of Technology, Cleveland, Ohio**

**1952 *Introduction to the Theory of Games*, J. McKinsey**

**1952 Product Form of the Inverse, A. Orden**

**1952 Blending Aviation Gasoline, A. Charnes , W. W. Cooper, B. Mellon**

**1952 UNIVAC I installed in The Pentagon to solve U.S. Air Force linear-programming problems**

***1953 The Institute of Management Sciences (TIMS) founded***

**1953 *The Theory of Inventory Management*, T. Whitin**

**1953 Operational Research Society (UK) founded**

**1953 *An Introduction to Linear Programming*, A. Charnes, W.W. Cooper, A. Henderson,**

**1953 Alternate Algorithm for the Revised Simplex Method: Using a Product Form of the Inverse,**

**G. Dantzig, W. Orchard-Hays**

**1954 "Traffic Delays at Toll Booths," L. C. Edie**

**1954 Parametric Programming , S. I. Gass, T. L. Saaty**

**1954 *Operations Research for Management*, J. McCloskey, F. Trefethen (eds.)**

**1954 *Naval Research Logistics Quarterly* established**

**1954 FORTRAN programming language, J. Backus, I. Ziller**

**1954 Sequencing and Scheduling (Johnson's Theorem), S. Johnson**

**1954 Dual Simplex Method, C. Lemke, E. Beale**

**1954 First ORSA Frederick W. Lanchester Prize to L. C. Edie**

**1954 *The Compleat Strategyst*, J. Williams**

**1955 Military Battle Models**

**1955 Traveling Salesman Problem, M. Flood**

**1955 Bounded Rationality/Satisficing, H. Simon**

**1955 Stochastic Programming, G. B. Dantzig**

**1955 Operations Research Center at MIT, P. Morse**

**1955 Hungarian Method for Transportation Problem, H. Kuhn, E. Egerváry**

**1956 Trim (cutting stock) Problem, A. E. Paull**

**1956 PERT/CPM/MPM, J. Kelley, Jr., W. Walker/D. Malcolm, J. Roseboom, C. Clark,**

**W. Fazar/B. Roy**

**1956 *The Theory of Games and Linear Programming*, S. Vajda**

**1956 Quadratic Programming, M. Frank, P. Wolfe**

**1957 First International Conference on OR (IFORS), Oxford**

**1957 Quadratic Assignment Problem, T. C. Koopmans, M. Beckmann**

**1957 *Introduction to Operations Research*, C. Churchman, E. Arnoff, R. Ackoff**

**1957 *Dynamic Programming*, R. Bellman**

**1957 *Games and Decisions: Introduction and Critical Survey*, R. D. Luce, H. Raiffa**

**1957 Jackson Networks, J. Jackson**

**1957 *Proceedings of the First International Conference on Operational Research*, M. Davies,**

**R. T. Eddison, T. Page (eds.)**

**1958 *Linear Programming and Associated Techniques: A Comprehensive Bibliography*, V. Riley,**

**S. I. Gass**

**1958 SIMSCRIPT, H. Markowitz**

**1958 *Linear Programming: Methods and Applications*, S. I. Gass**

**1958 Integer Programming, R. Gomory**

**1958 *Readings in Linear Programming*, S. Vajda**

**1958 *Queues, Inventory and Maintenance*, P. M. Morse**

**1958 *Linear Programming and Economic Analysis*, R. Dorfman, P. A. Samuelson, R. Solow**

**1958 *Scientific Programming in Business and Industry*, A. Vazsonyi**

**1959 *Mathematical Methods and Theory in Games*, Programming and Economics, I, II, S. Karlin**

**1959 Chance-Constrained Programming, A. Charnes, W. Cooper**

**1959 Dantzig-Wolfe Decomposition, G. B. Dantzig, P. Wolfe**

**1959 *Mathematical Methods of Operations Research*, T. Saaty**

**1959 Shortest Route Problem, E. Dijkstra**

**1959 International Federation of Operational Research Societies (IFORS)**

**1960 Branch and Bound, A. Land, A. Doig, R. Dakin, J. Little, K. Murty, D. Sweeney, C. Karel**

**1960 Facility Location**

**1960 Cost Effectiveness Analysis**

**1960 Value Theory, P. Fishburn**

**1960 Planning, Programming and Budgeting (PPB)**

**1960 Artificial Intelligence and OR**

**1960 Airline Group of the International Federation of Operations Research Societies (AGIFORS)**

**1960 Decision Trees**

**1960 Vehicle Traffic Science, R. Herman, D. Gazis, G. Newell, R. Oliver, I. Prigogine**

**1960 Cost Effectiveness Analysis**

**1960 *Stochastic Processes*, L. Takács**

**1960 *Finite Markov Chains*, J. G. Kemeny, J. Laurie Snell**

**1960 *Dynamic Programming and Markov Processes*, R. A. Howard**

**1960 *Planning Production, Inventories, and Work Force*, C. Holt, F. Modigliani, J. Muth, H. Simon**

**1961 International Abstracts in Operations Research (IAOR) established**

**1961 GPSS/Simulation Language, G. Gordon**

**1961 *Elements of Queueing Theory*, T. L. Saaty**

**1961 *Queues*, D. Cox and W. Smith**

**1961 Research Analysis Corporation (RAC)**

**1961 *Industrial Dynamics*, J. Forrester**

**1961 Little's Law, J. Little**

**1961 Packet Switching Theory, L. Kleinrock**

**1961 Geometric Programming , C. Zener**

**1962 Benders Partitioning Method, J. Benders**

**1962 Chinese Postman's Problem, M.- K. Kwan**

**1962 *Renewal Theory*, D. Cox**

**1962 *Flows in Networks*, L. Ford, Jr., D. Fulkerson**

**1962 *Smoothing, Forecasting and Prediction of Discrete Time Series*, R. Brown**

**1962 Fuzzy Set Theory, L. Zadeh**

**1962 Center for Naval Analyses**

**1963 *Analysis of Inventory Systems*, G. Hadley and T. Whitin**

**1963 *Linear Programming and Extensions*, G. Dantzig**

**1963 Delphi Method, N. Dalkey and O. Helmer**

**1963 Implicit Enumeration/Additive Algorithm, E. Balas, A. Geoffrion**

**1964 Social Welfare Function, Impossibility Theorem, K. Arrow**

**1964 *Analysis for Military Decisions*, E. S. Quade (ed.)**

**1964 Vehicle Routing Savings Algorithm, Clarke and Wright**

**1965 *Management Models and Industrial Applications of Linear Programming*, A. Charnes,**

**W. W. Cooper**

**1965 Complexity Theory; NP-Complete, J. Edmonds, R. Karp**

**1965 Goal Programming, A. Charnes, W. Cooper**

**1965 The Knapsack Problem, G. B. Dantzig**

**1965 Political Redistricting, S. Hess, J. Weaver, H. Seigfeldt, J. Whelan, P. Zitlau**

**1966 *A First Course in Stochastic Processes*, S. Karlin**

**1967 *Introduction to Operations Research*, F. Hillier, G. Lieberman**

**1967 *Theory of Scheduling*, R. Conway, W. Maxwell, L. Miller**

**1967 Criminal Justice: President's Crime Commission Science and Technology Task Force,**

**A. Blumstein, S. I. Gass, R. C. Larson**

**1967 *Geometric Programming*, R. Duffin, E. Peterson, C. Zener**

**1968 Surrogate constraints, F. Glover**

**1968 *Nonlinear Programming: Sequential Unconstrained Minimization Techniques*, A. Fiacco,**

**G. McCormick**

**1968 Metric (Multi-Echelon Technique for Recoverable Item Control), C. Sherbrooke**

**1968 Decision Analysis, R. Howard**

**1968 Outranking Procedure (ELECTRE) for Multi-Attribute Decision Making, B. Roy**

**1969 Advertising, J. Little, L. Lodish**

**1969 *Principles of Operations Research*, H. Wagner**

**1969 *System Simulation*, G. Gordon**

**1969 New York City RAND Institute**

**1969 First ARPANET/INTERNET site at UCLA, L. Kleinrock**

**1970 *Time Series Analysis*, G. Box, G. Jenkins**

**1971 *Marketing Decision Making: A Model Building Approach*, P. Kotler**

**1971 ORSA's journal *OR/SA Today* established**

**1971 *World Dynamics*, J. Forrester**

**1971 Computational Complexity, S. A. Cook, R. Karp**

**1972 *Limits to Growth*, D. Meadows et al.**

**1972 International Institute for Applied Systems Analysis (IIASA)**

**1972 Soft Systems Methodologies, P. Checkland**

**1972 Sweep Algorithm for Vehicle Routing, B. Gillett, L. Miller**

**1972 First Franz Edelman Award for Management Science Achievement presented to The Pillsbury**
**Company**

**1972 Klee-Minty problem showed that the simplex method is not a polynomial-time algorithm,**
**V. Klee and G. J. Minty**

**1973 Decision Support Systems, P. Keen, S. Morton**

**1974 *Computers and Operations Research* established**

**1974 Hypercube Queueing Model, R. C. Larson**

**1974 OR established in Federal Express**

**1974 First joint ORSA and TIMS meeting**

**1974 *OR/MS Today* established (first joint ORSA/TIMS publication)**

**1974 TIMS's *Interfaces* becomes joint publication of TIMS and ORSA**

**1974 SLAM, GASP/Simulation Languages, A. Pritsker**

**1974 "*A Guide to Models in Governmental Planning and Operations*, S. I. Gass, R. Sisson (eds.)**

**1974 "*Fundamentals of Queueing Theory*," D. Gross, C. Harris**

**1975 Multicriteria Decision Making, M. Zeleny, S. Zionts, J. Wallenius, W. Edwards, B. Roy**

**1975 First von Neumann Prize (ORSA) to George B. Dantzig**

**1975 Analysis for Public Decisions, E. Quade**

**1975 *Queueing Systems, Vol. I: Theory*, L. Kleinrock**

**1976 *Queueing Systems, Vol. II: Computer Applications*, L. Kleinrock**

**1976 *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, R. Keeney, H. Raiffa**

**1976 *Models in the Public Policy*, M. Greenberger, M. Crenson, B. Crissey**

**1976 Quality Control, G. Taguchi**

**1977 *Models for Public Systems Analysis*, E. Beltrami**

**1977 Anti-Cycling Rules for Linear-Programming Problem, R. Bland**

**1977 *Manpower Planning*, R. Grinold, K. Marshall**

**1978 Data Envelopment Analysis (DEA), A. Charnes, W. Cooper, E. Rhodes**

**1978 Lagrangian Relaxation, A. Geoffrion**

**1979 Ellipsoid Method, L. Khachian**

**1979 "Airline Safety: An Empirical Study," A. Barnett, M. Abraham, V. Schimmel**

**1980 Spreadsheet OR add-in software**

**1980 Constraint Programming**

**1980 *The Analytic Hierarchy Process*, T. Saaty**

**1980 Parallel Computing**

**1980 LINDO, L. Schrage**

**1980 Conflict Analysis**

**1980 Revenue (Yield) Management, American Airlines, T. Cook**

**1981 *Urban Operations Research*, R. C. Larson, A. Odoni**

**1982 Expert systems, A. Barr, E. Fiegenbaum**

**1982 Simulated Annealing, W. Metropolis**

**1982 Average Running Time of Simplex Method Shown to be Polynomially Bounded,**

**K.-H. Borgwardt**

**1984 Neural Networks, J. Hopfield**

**1984 Interior Point Methods, N. Karmarkar**

**1984 *What's Best,* S. Savage, K. Cunnigham, G. Link**

**1984 PROMETHE Method for Multi-Attribute Decision Making, J.-P. Brans, B. Mareschal,**

**P. Vinke**

**1985 Flexible Manufacturing Systems**

**1985 Airline Crew and Aircraft Scheduling**

**1985 *Handbook of Systems Analysis: Craft Issues and Procedural Choices*, H. Miser, E. Quade**

**1986 Burger King receives OR practice award**

**1988 American Airlines Decision Technologies, T. Cook**

**1988 General Algebraic Modeling System/GAMS, A. Meeraus**

**1989 Tabu Search, F. Glover**

**1990 Desert Shield military airlift**

**1990 Supply Chain Management**

**1990 Financial Engineering, W. Ziemba, S. Zenios, J. Mulvey**

**1990 Geographical Information Systems**

**1990 Evolutionary Algorithms**

**1991 American Airlines and Federal Express receive the INFORMS Prize**

**1991 OR and Persian Gulf War**

**1992 San Miguel Corporation receives the INFORMS Prize**

**1993 NYC's Office of Management and Budget and United Airlines receive the INFORMS Prize**

**1994 Network-Enabled Optimization System (NEOS)**

**1994 AT&T and US West Technologies receive the INFORMS Prize**

**1995 Data Mining**

**1995 INFORMS formed by merger of ORSA and TIMS**

**1995 Bellcore receives the INFORMS Prize**

**1995 Online Analytical Processing (OLAP)**

**1995 Enterprise Resource Planning (ERP)**

**1995 INFORMS OnLine**

**1996 *Encyclopedia of Operations Research and Management Science*, S. Gass, C. Harris**

**1996 e-Commerce**

**1996 Center for Excellence in Aviation Operations Research (Berkeley, MIT, U of MD, VPI&SU)**

**1996 Pfizer, Inc. receives the INFORMS Prize**

**1997 Merrill Lynch Private Client Group receives the INFORMS Prize**

**1998 Lucent Technologies receives the INFORMS Prize**

**1999 IBM receives the INFORMS Prize**

**2000 50th anniversary of the publication of the *Journal of Operational Research***

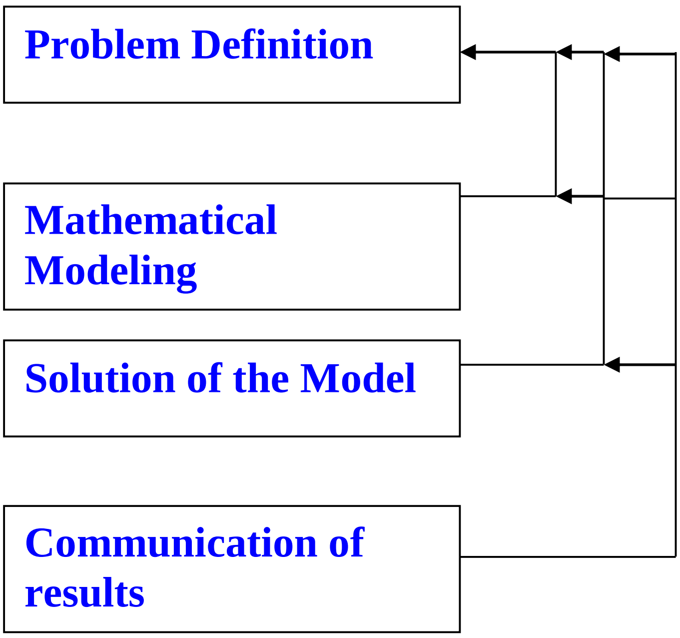
**2001 50th anniversary of the OR program at the Naval Post Graduate School**

**2002 50th anniversary of the founding of ORSA**

**2002 50th anniversary of the publication of *Operations Research***

## Management Science Process

**Management science is a discipline that adopts the scientific method to provide management with key information for executive decision-making. In its simplest form, management-science can be thought of as a four step procedure as shown in the following figure.**



# Problem Definition

1. **Observe operations**
2. **Ease into complexity**
3. **Recognize political realities**
4. **Decide what is really wanted**
5. **Identify constraints**
6. **Seek continuous feedback**

## The Methodology of Operations Research

1. **Formulate the problem**
2. **Observe the system**
3. **Formulate a Mathematical model of the problem**
4. **Verify the model and use the model for prediction**
5. **Select a suitable alternative**
6. **Present the results and conclusions of the study to the organization**
7. **Implement and evaluate recommendations**

# Classification of Mathematical Models

## By the Purpose of the Model

- **Optimization Models**
- **Prediction Models**

## By the degree of the certainty

- **Deterministic models**
- **Probabilistic models or Stochastic Models**

## MS/OR IS GENERALLY APPPLIED
## IN THREE SITUTIONS

1. **Designing and implementing new operations or procedures**
2. **Evaluating an ongoing set of operations or procedures**
3. **Determining and recommending corrective action for operations and procedures that are producing unsatisfactory results.**

**Management is also applied when a company has experienced significant or repetitious failures or shortfalls.**

# An analyst is typically faced with some or all of the following factors.

1. **“Fuzzy”, incomplete or conflicting data,**
2. **“Soft” constraints,**
3. **Differing opinions among and between workers and management,**
4. **Very limited budgets for analyses,**
5. **Narrow time frames for solutions and recommendations**
6. **Political “turf wars”,**
7. **No firm idea by management of exactly what is wanted.**

# MANAGEMENT SCIENCE TECHNIQUES

***Linear Programming:*** ***Linear programming is a problem-solving approach that has been developed for situations involving maximizing or minimizing a linear function subject to linear constraints that limit the degree to which the objective can be pursued.***

***Integer Linear Programming:*** ***Integer linear programming is an approach used for problems that can be set up as linear programs with the additional requirement that some or all of the decision recommendations be integer values.***

***Network Models:*** ***A network is a graphical description of a problem consisting of circles called nodes that are interconnected by lines called arcs. Specialized solution procedures exist for these types of problems, enabling us to quickly solve many managerial problems in such areas as transportation system design, information system design, and project scheduling.***

***Project Management:*** ***PERT/CPM In many situations managers assume the responsibility for planning, scheduling, and controlling projects that consist of numerous separate jobs or tasks performed by a variety of departments, individuals, etc. PER and CPM are techniques for helping managers carry out their project management responsibilities.***

***Inventory Models:*** ***Inventory models are used to help managers faced with the dual problems of maintaining sufficient inventories to meet demand for goods and, at the same time, incurring the lowest possible inventory holding costs.***

***Waiting Line or Queuing Models:*** ***Waiting line or queuing models have been developed to help managers understand and make better decisions concerning the operation of systems involving waiting lines.***

***Computer Simulation:*** ***Computer simulation is a technique used to model the operation of a system over time. This technique employs a computer program to model the operation and perform simulation computations.***

***Decision Analysis:*** ***Decision analysis can be used to determine optimal strategies in situations involving several decision alternatives and an uncertain or risk-filled pattern of events.***

***Goal Programming**: Goal programming is a technique for solving multi-criteria decision problems, usually within the framework of linear programming.*

***Analytic Hierarchy Process:*** ***A multi-criteria decision-making technique that permits the inclusion of subjective factors in arriving at a recommended decision.***

***Forecasting:*** ***Forecasting methods are techniques that can be used to help predict future aspects of a business operation.***

***Markov Process Models:*** ***Markov process models are useful in studying the evolution of certain systems over repeated trials. For example, Markov processes have been used to describe the probability that a machine that is functioning in one period will continue to function of break down in another period.***

***Dynamic Programming:*** ***Dynamic programming is an approach that allows us to break up a large problem in such a fashion that once all the smaller problems have been solved, we are left with an optimal solution to large problem.***

## The utilization of Management Science and Operations Research Methodologies*

### Frequency of use % of respondents

| | Never | Moderate | Frequent |
|---|---|---|---|
| Statistical | 1.6 | 38.7 | 59.7 |
| Computer Simulation | 12.9 | 53.2 | 33.9 |
| PERT/CPM | 25.8 | 53.2 | 21.0 |
| Linear Programming | 25.8 | 59.7 | 14.5 |
| Queuing Theory | 40.3 | 50.0 | 9.7 |
| Nonlinear Programming | 53.2 | 38.7 | 8.1 |
| Dynamic Programming | 61.3 | 33.9 | 4.8 |
| Game Theory | 69.4 | 27.4 | 3.2 |

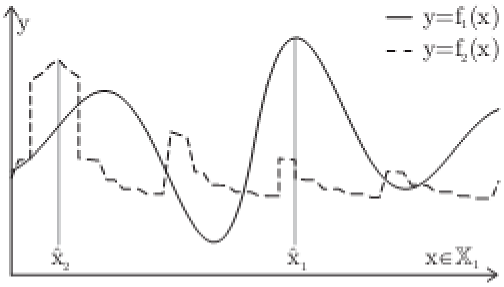
## Familiarity with and use of various quantitative methods by management science practitioners*

| | Familiarity Rank | Usage (%) |
|---|---|---|
| Linear Programming | 1 | 83.8 |
| Simulation | 2 | 80.3 |
| Network Analysis | 3 | 58.1 |
| Queuing Theory | 4 | 54.7 |
| Decision Trees | 5 | 54.7 |
| Integer Programming | 6 | 38.5 |
| Dynamic Programming | 7 | 32.5 |
| Nonlinear Programming | 8 | 30.7 |
| Markov Processes | 9 | 31.6 |
| Replacement analysis | 10 | 38.5 |
| Game Theory | 11 | 13.7 |
| Goal Programming | 12 | 20.5 |

*C.L. Morgan, “A survey of MS/OR Surveys, Interfaces 19.no 6.

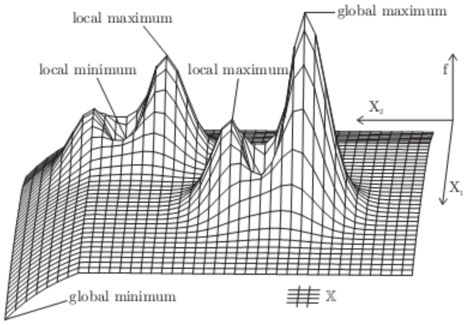
# OPTIMIZATION CLASSIFICATION

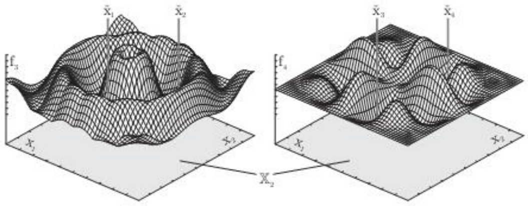
**Optimization may be defined as the process by which an optimum is achieved.**



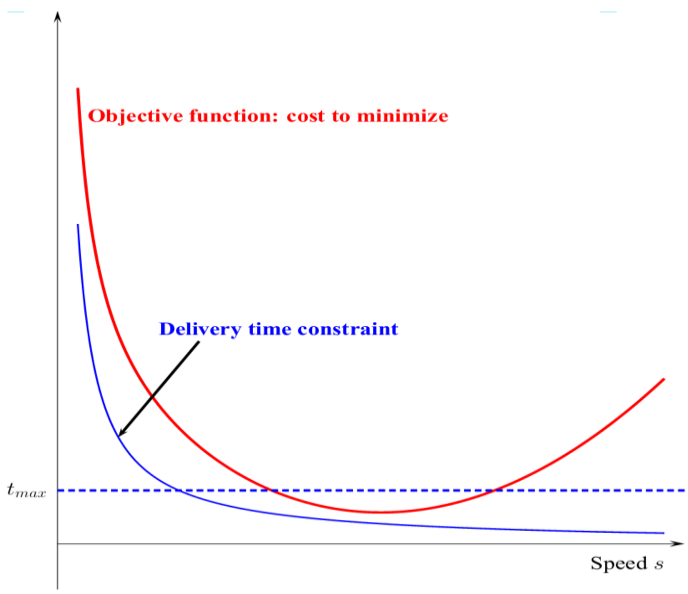

- ✓**Optimization of Univariate Functions**
- ✓**Optimization of Multivariate Functions**

**Optimizations may be performed for obtaining local and global optima.**



- ✓ **The optimum may be that of an industrial institution or an objective function that models a similar entity.**
- ✓ **The factors that define the optimum will vary with the situation to which the optimization process is applied.**
- ✓ **Some examples of factors that may be optimized are cost, raw materials used, time required and pollution caused.**



- ✓ Optimization without constraints
- ✓ Optimization with constraints

## Unconstrained Optimization

- ✓ **Classical Methods**
  - **Functions of one variable**
  - **Functions of n Variables**
- ✓ **Search Methods-Functions of one variable**
  - **Fibonacci Search**
  - **Golden Section Search**
  - **The Curve Fitting Approaches**
  - **Quadratic Interpolation**
  - **Cubic Interpolation**
- ✓ **Direct Search Methods-Functions of n variables**
  - **The Method of Hooke and Jeeves**
  - **Nelder and Mead's Method**
- ✓ **Gradient Methods**
  - **Steepest Descent Method**
  - **Quadratic Functions**
  - **The Davidon-Fletcher-Powell Method**
  - **The Fletcher-Reeves Method**

## Constrained Optimization

- ✓ **Classical Methods**
  - **Equality Constraints**
  - **Inequality Constraints**
  - **Convexity and Concavity**
- ✓ **Search Methods**
  - **Modified Hook and Jeeves**
  - **The complex Method**
- ✓ **Nonlinear Constraint Optimization**

**The standard form of the constrained optimization problem is as follows:**

| | | |
|---|---|---|
| *Minimize* | $f(x)$ | |
| *Subject to* | $g_j(x) \le 0,$ | $i = 1, \ldots, p$ |
| | $h_i(x) = 0,$ | $j = 1, \ldots, m$ |

**where x has dimensions nx1, f(x) is the objective function to be minimized, g(x) are a set of inequality constraints, and h(x) are a set of equality constraints.**

## Lagrange multipliers

If $F(x, y)$ is a (sufficiently smooth) function in two variables and $g(x, y)$ is another function in two variables, and we define $H(x, y, z) := F(x, y) + zg(x, y)$, and $(a, b)$ is a relative extremum of $F$ subject to $g(x, y) = 0$, then there is some value $z = \lambda$ such that $\frac{\partial H}{\partial x}|_{(a,b,\lambda)} = \frac{\partial H}{\partial y}|_{(a,b,\lambda)} = \frac{\partial H}{\partial z}|_{(a,b,\lambda)} = 0$.

## Example of use of Lagrange multipliers

Find the extrema of the function $F(x, y) = 2y + x$ subject to the constraint $0 = g(x, y) = y^2 + xy - 1$.

## Solution

Set $H(x, y, z) = F(x, y) + zg(x, y)$. Then

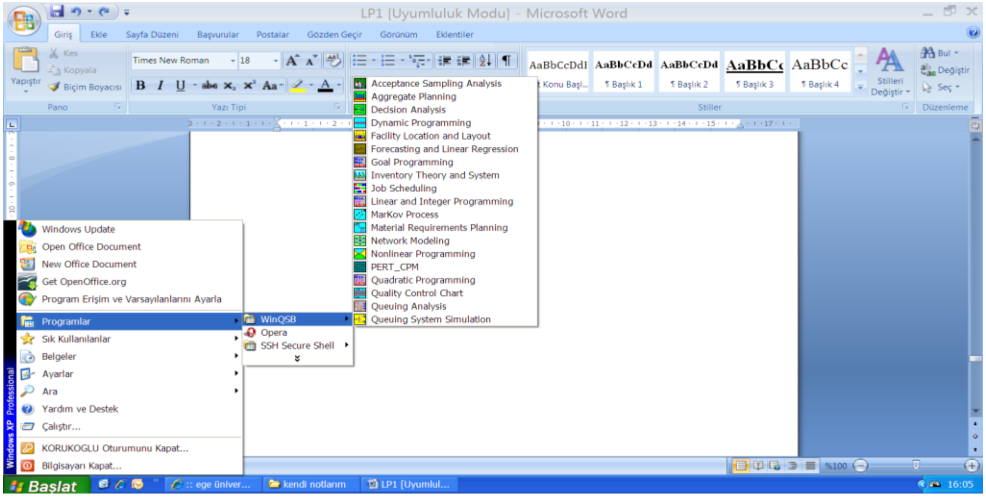
$$\begin{aligned}\frac{\partial H}{\partial x} &= 1 + zy \\ \frac{\partial H}{\partial y} &= 2 + 2zy + zx \\ \frac{\partial H}{\partial z} &= y^2 + xy - 1\end{aligned}$$

## Solution, continued

Setting these equal to zero, we see from the third equation that $y \neq 0$, and from the first equation that $z = \frac{-1}{y}$, so that from the second equation $0 = \frac{-x}{y}$ implying that $x = 0$. From the third equation, we obtain $y = \pm 1$.

# Nonlinear constraint optimization software

| Name | Model | Global Method | Interfaces |
|---|---|---|---|
| ALGENCAN | Aug. Lag. | augmented | AMPL, CUTEr Java, MATLAB, Octave, Python, R |
| CONOPT | GRG/SLQ | line-search | AIMMS, GAMS |
| CVXOPT | IPM | only convex | Python |
| FilterSQP | SQP | filter/trust region | AMPL, CUTEr, |
| GALAHAD | Aug. Lag. | nonmonotone/ augmented | CUTEr, Fortran |
| IPOPT | IPM | filter/line search | AMPL, CUTEr, C, C++, |
| KNITRO | IPM | penalty-barrier/ trust region | AIMMS, AMPL, Mathematica, MATLAB, MPL, C, C++, f77, Excel |
| KNITRO | SLQP | penalty/trust region | s.a. |
| LANCELOT | Aug. Lag. | augmented trust region | SIF, AMPL, f77 |
| LINDO | GRG/SLP | only convex | C, MATLAB, LINGO |
| LOQO | IPM | line search | AMPL, C, MATLAB |
| LRAMBO | SQP | $\ell_1$ exact penalty/ line search | C |
| MINOS | Aug. Lag. | augmented | AIMMS, AMPL, MATLAB, C, C++, f77 |
| NLPQLP | SQP | augmented line-search | C, f77, MATLAB |
| NPSOL | SQP | penalty Lagrangian/ line search | AIMMS, AMPL, MATLAB, C, C++, f77 |
| PATH | LCP | line search | AMPL |
| PENNON | Aug. Lag. | line search | AMPL, MATLAB |
| SNOPT | SQP | penalty Lagrangian/ line search | AIMMS, AMPL, MATLAB, C, C++, f77 |
| SQPlab | SQP | penalty Lagrangian/ line search | MATLAB |


LP1 [Uyumluluk Modu] - Microsoft Word
Acceptance Sampling Analysis
Aggregate Planning
Decision Analysis
Dynamic Programming
Facility Location and Layout
Forecasting and Linear Regression
Goal Programming
Inventory Theory and System
Job Scheduling
Linear and Integer Programming
MarKov Process
Material Requirements Planning
Network Modeling
Nonlinear Programming
PERT_CPM
Quadratic Programming
Quality Control Chart
Queuing Analysis
Queuing System Simulation
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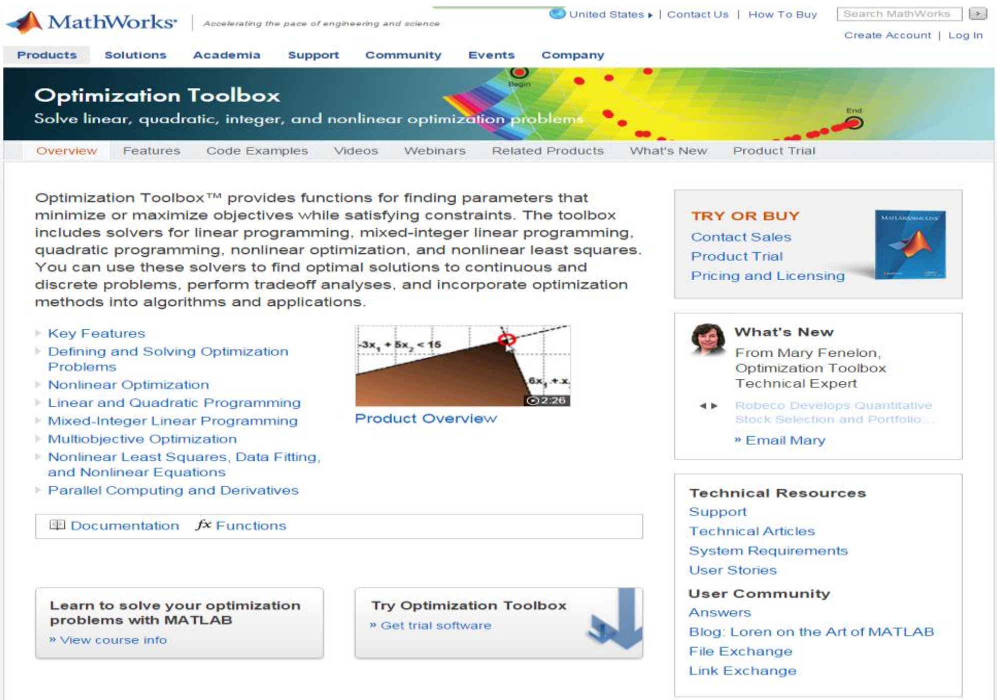
WinQSB
Opera
SSH Secure Shell
Sık Kullanılanlar
Belgeler
Ayarlar
Ara
Yardım ve Destek
Çalıştır...
KORUKOGLU Oturumunu Kapat...
Bilgisayarı Kapat...
Başlat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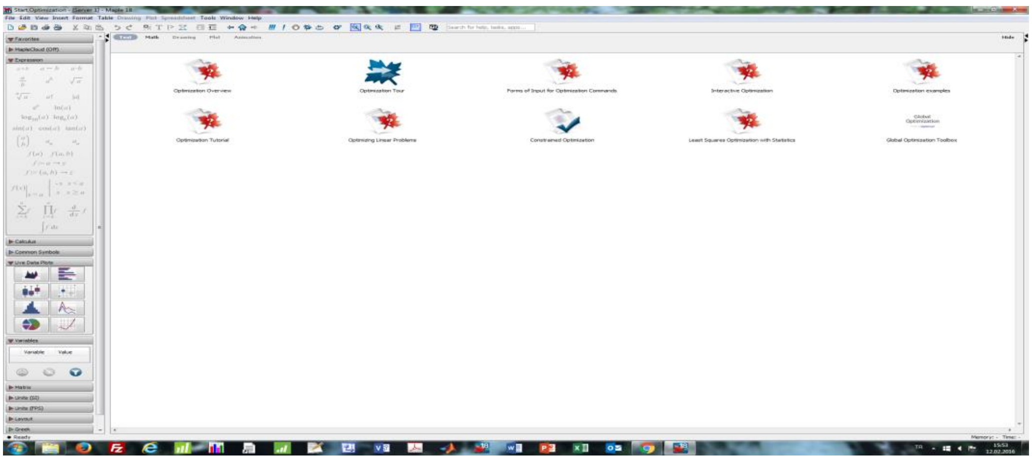


# Optimization Tasks

- ✓ **By Solving Method**
  - **Linear Programming**
  - **Quadratic Programming**
  - **Nonlinear Programming**
  - **Dynamic Programming**
  - **Integer Programming**
    - **Binary Programming**
  - **Mixed Integer Programming**

- ✓ **By number of Criteria**
  - **Single Criterion**
  - **Multi Criterion**

## Definition of a multi-objective optimization problem

The general multi-objective optimization problem is posed as follows:

$$\underset{\mathbf{x}}{\text{Minimize}}\ \mathbf{F}(\mathbf{x}) = [F_1(\mathbf{x}), F_2(\mathbf{x}), \ldots, F_k(\mathbf{x})]^T$$
$$\text{subject to } g_j(\mathbf{x}) \leq 0\,, \quad j = 1, 2, \ldots, m\,, \tag{1}$$

$$h_l(\mathbf{x}) = 0\,, \quad l = 1, 2, \ldots, e\,,$$

where $k$ is the number of objective functions, $m$ is the number of inequality constraints, and $e$ is the number of equality constraints. $\mathbf{x} \in E^n$ is a vector of *design variables* (also called *decision variables*), where $n$ is the number of independent variables $x_i$. $\mathbf{F}(\mathbf{x}) \in E^k$ is a vector of objective functions $F_i(\mathbf{x}) : E^n \to E^1$. $F_i(\mathbf{x})$ are also called objectives, *criteria*, *payoff functions*, *cost functions*, or *value functions*. The gradient of $F_i(\mathbf{x})$ with respect to $\mathbf{x}$ is written as $\nabla_{\mathbf{x}} F_i(\mathbf{x}) \in E^n$. $\mathbf{x}_i{}^*$ is the point that minimizes the objective function $F_i(\mathbf{x})$. Any comparison $(\leq, \geq, \text{etc.})$ between vectors applies to corresponding vector components.

**Multi-objective optimization often means to compromise conflicting goals.**

- ✓ **Minimize the time between an incoming order and the shipment of the corresponding product,**
- ✓ **Maximize profit,**
- ✓ **Maximize product quality**
- ✓ **Minimize negative impact on environment,**
- ✓ **Minimize cost for advertising,**
- ✓ **Minimize cost for personal,**
- ✓ **Minimize cost for raw materials,**

# Global optimization

Global optimization is the task of finding the absolutely best set of parameters to optimize an objective function. In general, there can solutions that are locally optimal but not globally optimal. Consequently, global optimization problems are typically quite difficult to solve exactly; in the context of combinatorial problems, they are often NP-hard. Their solution often requires a global search approach. Global optimization problems fall within the broader class of nonlinear programming (NLP).

A few application examples include acoustics equipment design,

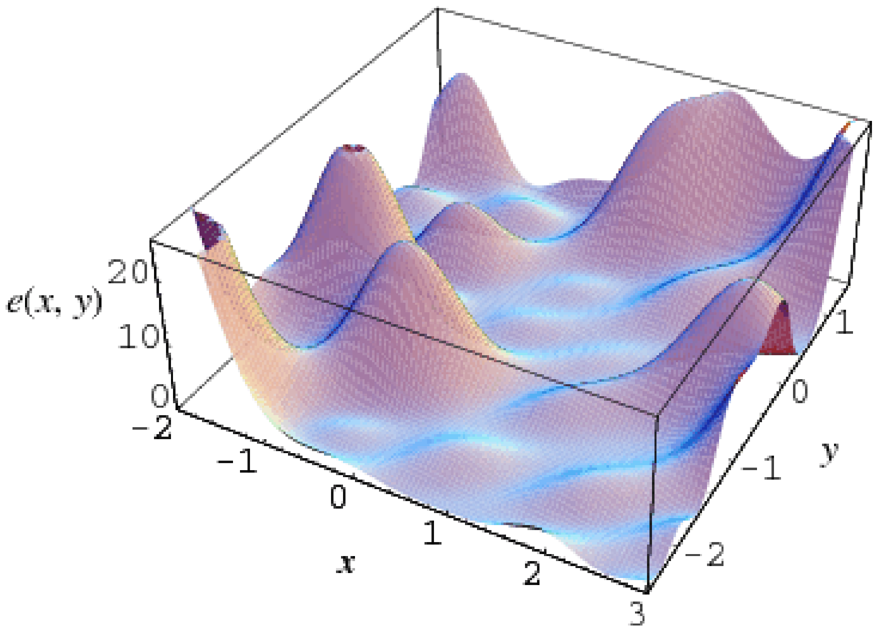
- ✓ cancer therapy planning,
- ✓ chemical process modeling,
- ✓ data analysis, classification and visualization,
- ✓ economic and financial forecasting,
- ✓ environmental risk assessment and management,
- ✓ industrial product design, laser equipment design, model fitting to data (calibration),
- ✓ optimization in numerical mathematics,
- ✓ portfolio management,
- ✓ potential energy models in computational physics and chemistry,
- ✓ Process control, robot design and manipulations, systems of nonlinear equations and inequalities, and waste water treatment systems management.

As an example, consider the $l_2$-norm error function related to solving the pair of equations

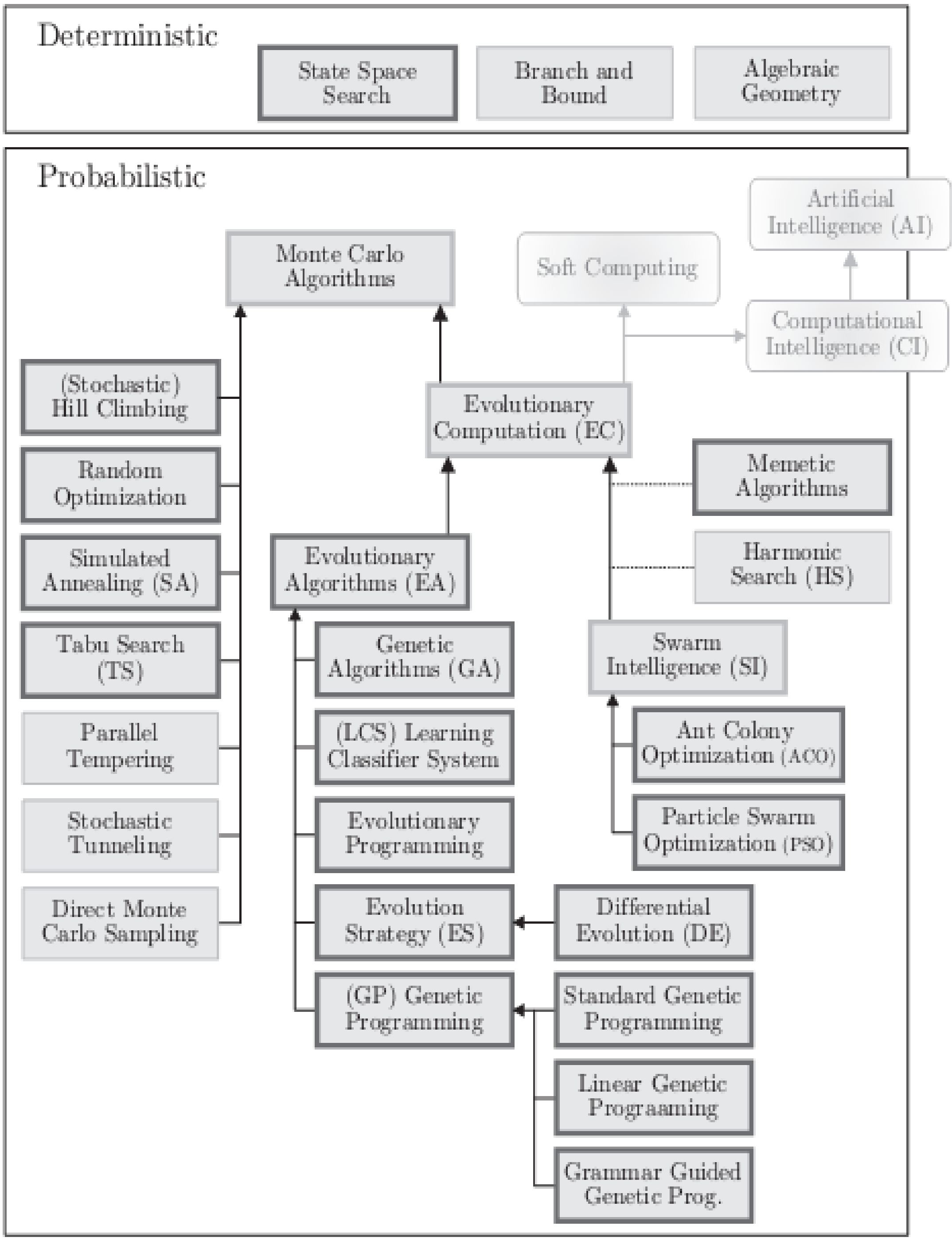
$$x - \sin(2x + 3y) - \cos(3x - 5y) = 0 \tag{1}$$

$$y - \sin(x - 2y) + \cos(x + 3y) = 0. \tag{2}$$

Since we wish to find the globally smallest error and not just a "locally smallest" one, we need to search globally in the two-dimensional box region (see the base area of the picture). There are great many nonlinear optimization problems that possess a similar multi-modal structure.



# The taxonomy of global optimization algorithms



## Simulated Annealing

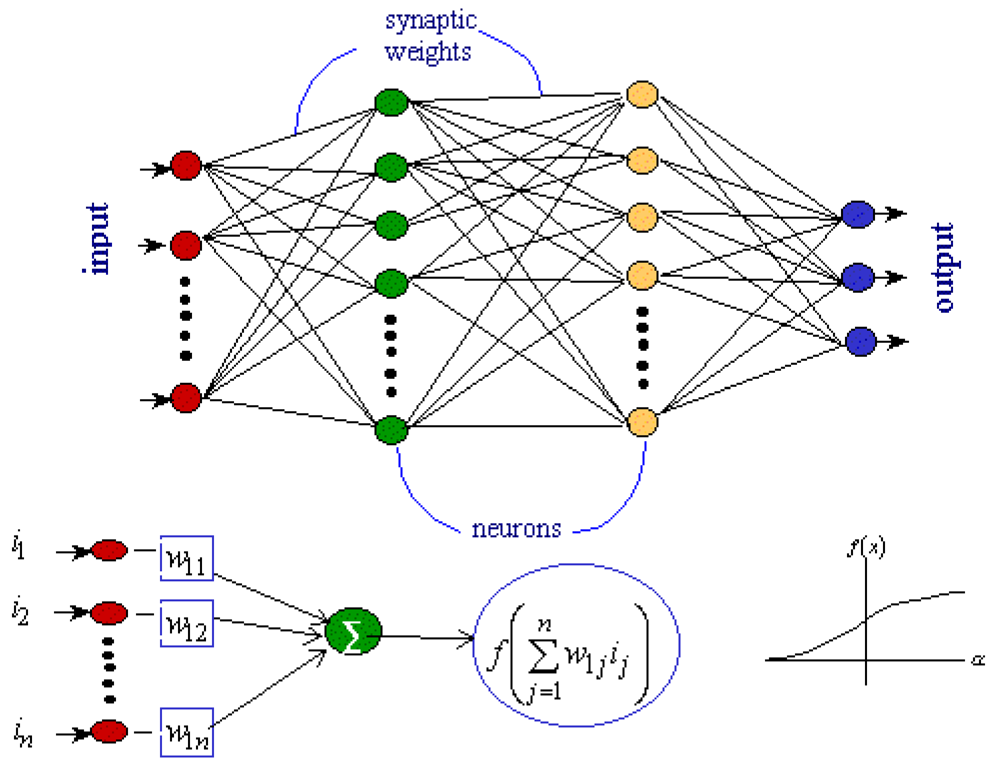
***<u>This technique draws its inspiration from the annealing process that many substances undergo while changing state</u>*****. Typically, a substance, such as iron for example, when heated gains energy. This energy is gradually dissipated due to cooling. The temperature is thus a measure of the disorder in the iron. As it cools its molecules gradually, loose energy and gain order. This process continues until the system can achieve thermodynamic equilibrium. In the case of annealing a piece of iron, thermodynamic equilibrium would occur when the temperature of the iron is the same as the temperature of the surroundings. Simulated Annealing tries to mimic this process and therefore gets its name.**

***<u>One of the difficulties in using Simulated Annealing is that it becomes very difficult to choose the rates of cooling and the initial temperatures for the system that is being optimized</u>*****. This occurs primarily because of the absence of any rules for selecting them. The selection of these parameters depends on heuristics and varies with the system that is being optimized.**

# Neural Networks

***Neural networks derive their inspiration from biological neuron systems and the brain. A neural network consists of a number of sub-units called neurons.***

**There has been an explosion of interest in Neural Networks. They have been applied to modeling as well as to interpretation. The major reason for the universal appeal and utility of neural networks is that they are universal approximators.**



## Genetic Algorithms

***These algorithms draw their inspiration from various hypotheses of biological evolution.*** **Historically, such hypotheses have proposed that species evolve through a process of survival of the fittest.**

- ***A population of a species (set of possible solutions in this case) is created.***
- ***The members of this species are allowed to reproduce and recombine to produce new offspring.***
- ***The fittest offspring are then selected to go on to the next stage namely, recombining and producing new offspring (or new solutions).***

***Initialize the population***
***Evaluate initial population***
***Repeat***
  ***Perform competitive selection***
  ***Apply genetic operators***
  ***to generate new solutions Evaluate solutions in the population***
***Until some convergence criteria is satisfied***

# Tabu Search

***This technique is based on the idea that humans behave in a seemingly random manner given the same learning environment.*** **The correct behavior or solution is discovered over time by performing a given action, determining its consequences and using those consequences in performing future actions. Hence, Tabu search must keep a track or 'list' of the paths it as traversed.**

**Tabu search has two main stages.**

- ***In the first stage it explores the state space coarsely and determines probable solutions.***

- ***In the second stage, it searches in the environs of these probable solutions to determine which solution is the best.***

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