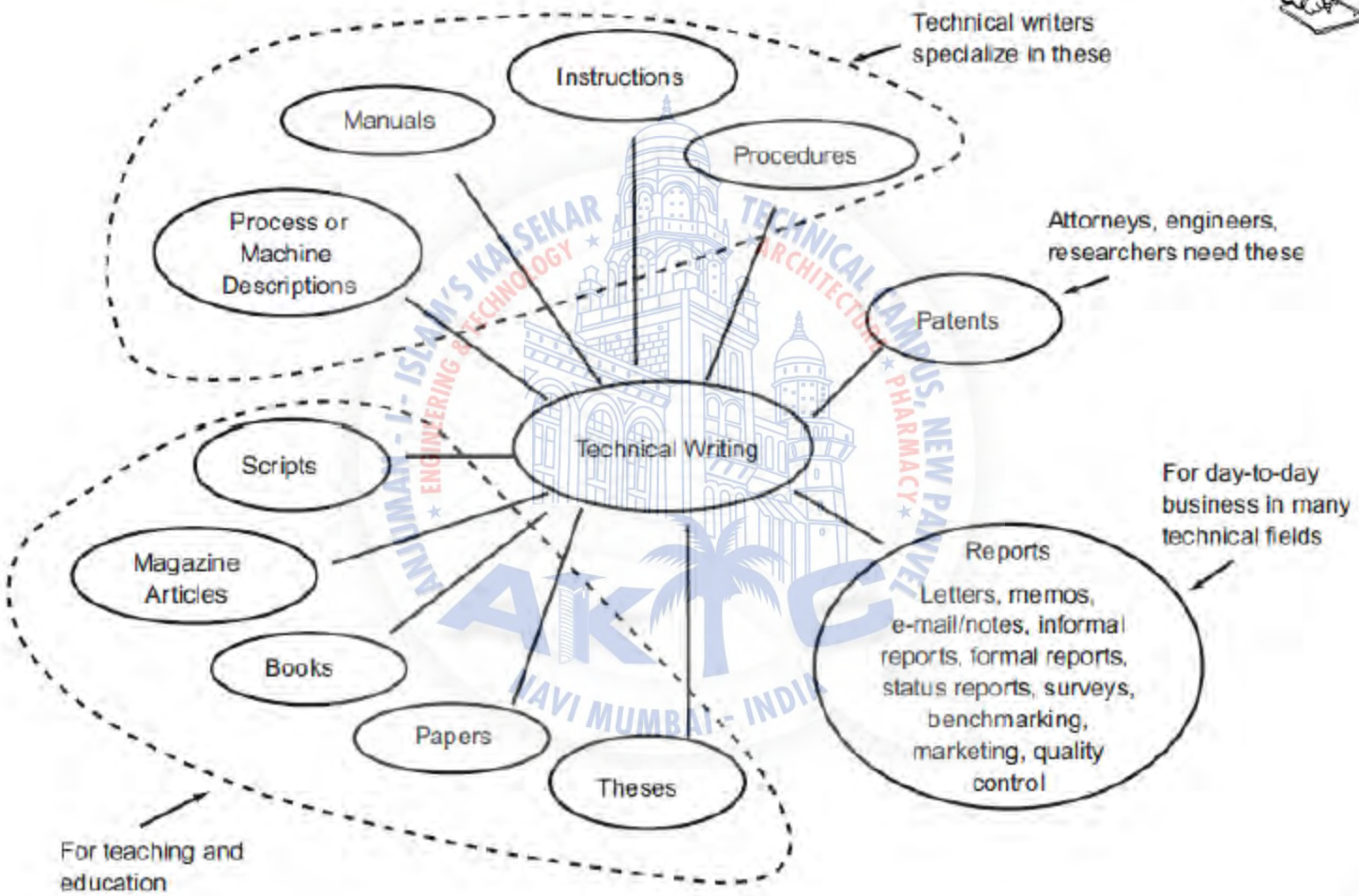
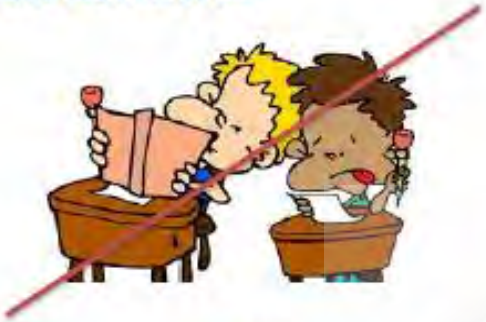
RESEARCH METHODOLOGY

Dr Abdul Razak H.

Types of scientific documents



Basic Requirements



Ethics

Knowledge

Skill

Basic Requirements

Ethics - Plagiarism = STEALING

Idea Theft

Copy Paste Theft

- Full Plagiarism - single source. incompetence, laziness
- Partial Plagiarism - various sources. cheating

Source citing - paraphrasing. Quotes. Reference.

Self Plagiarism - Fraud

Honesty is the best policy

Basic Requirements

Skill is 99% practice, 1% talent

Skill

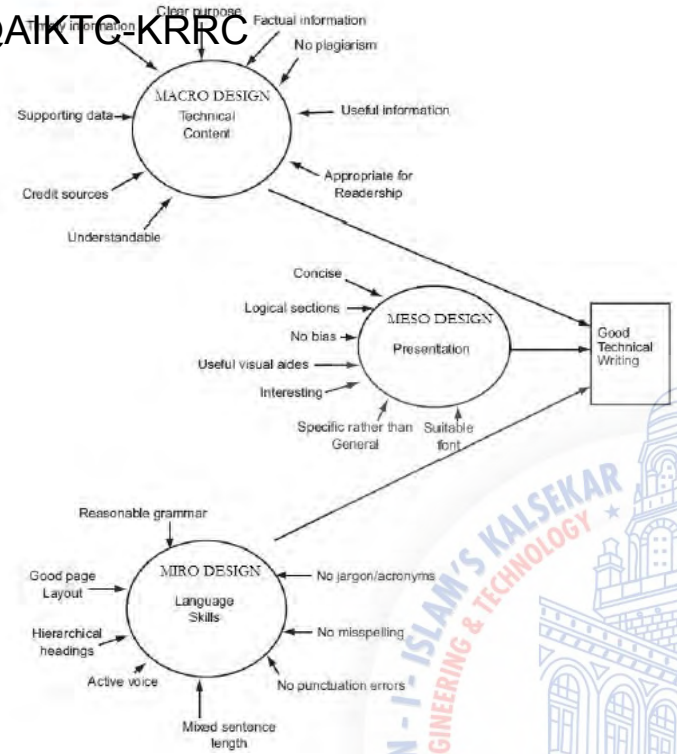
Commitment: Focus, goals, sincerity

Organization: Good book-keeping, filing, planning

Talent: Good grammatical skills

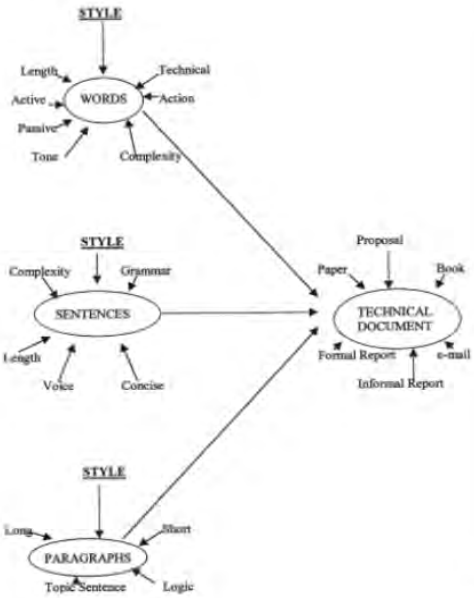
"We Learn To Write By Reading, But Writing Can Make You Smarter,"

- Dr. Stephen Krashen

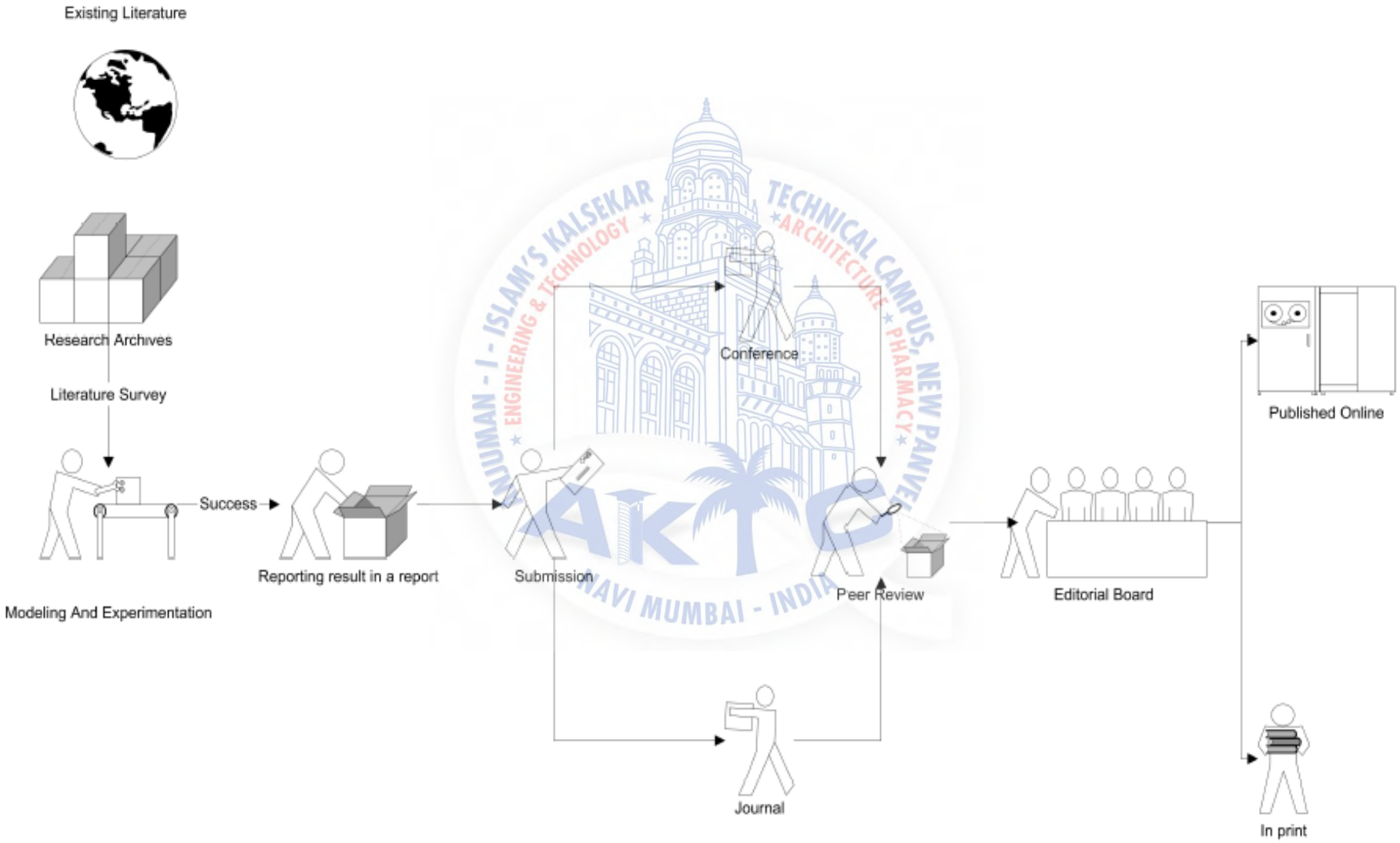


Micro Design

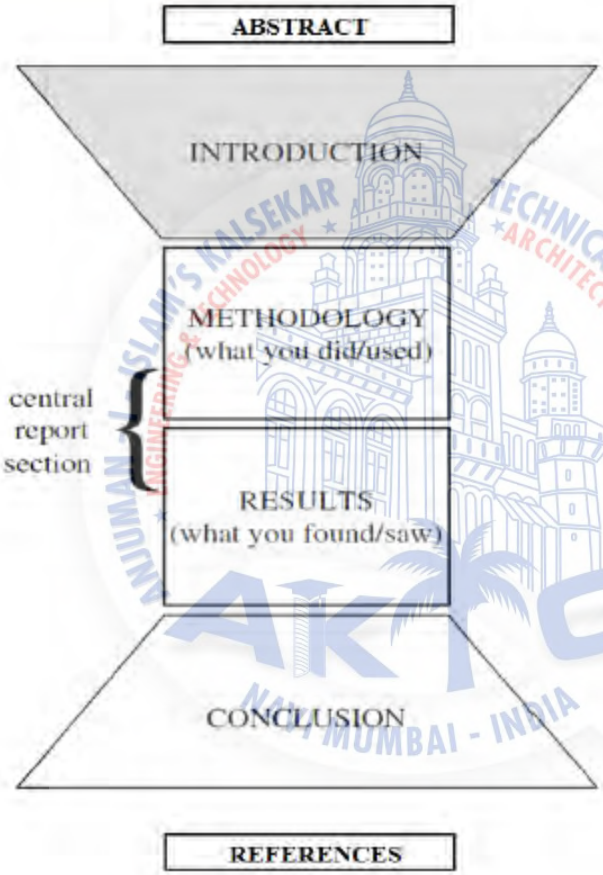
- Word construction
- Sentence construction
- Paragraphing



Research and Publication Process



Structure of a scientific document



AIMRAD Structure

Abstract
Introduction
Method
Result
And
Discussion

"Writing is an exploration. You start from nothing and learn as you go."

- E. L. Doctorow

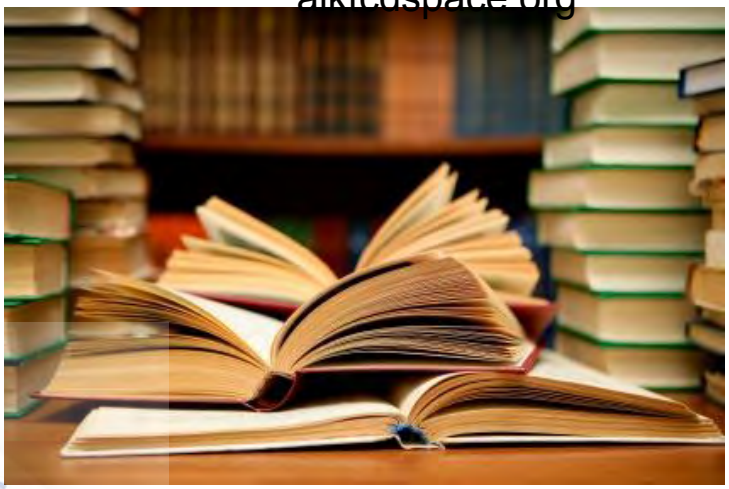
RESEARCH DEFINITION

The search for knowledge

OR

Any systematic investigation, with an open mind, to establish novel facts, solve new or existing problems, prove new ideas, or develop new theories.

PRIMARY PURPOSE



- Documentation,
- Discovery,
- Interpretation, or
- Research and Development

of methods and systems for the advancement of

Human Knowledge.

WHY RESEARCH?

1. Do you want to find answers to fundamental questions?

2. Do you get satisfaction from solving problems?

3. Do you want to build something?

4. Do you value the freedom to do what?

5. Interests you and what you think important?

WHAT IS PhD?

PhD is not just about doing Research but is a journey from

"Intellectual Joy to Self Actualization"

1.It is learning about how to do research…

2.Highest professional degree taking to the top of the academic and professional ladder…

3.It is beginning of one's Research career **(License to do Research)**

4.Search for more and more knowledge, and trains to do quality work for the rest of life.

5.It is not about learning existing knowledge but about creating new knowledge, innovations and inventions.

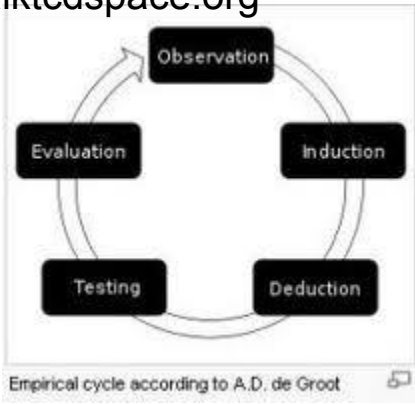
WHY PhD ?

- Indian industry shifts from **"earning through services"** paradigm towards R&D and intellectual property creation…

- Multinationals are starting their operations in India and looking for intellectuals…

For all the above requirements, more and more professionals required,

Thus **quality faculty** required to create them…

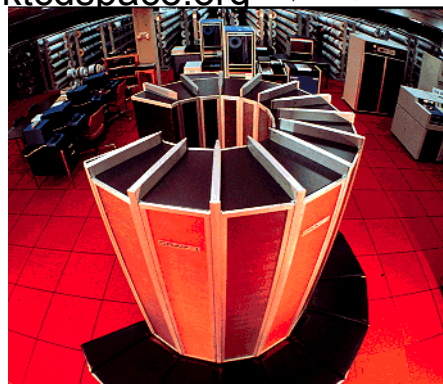


Empirical cycle according to A.D. de Groot

What is involved in doing PhD?

- It is about finding solution to a researchable problem…
- Formulating problems whose answers are important / interesting…
- Answers we want to know but we do not know…
- Solve such problems and get peer review by writing thesis and papers…
- Major requirement is to do original research…

Nature of Research problems



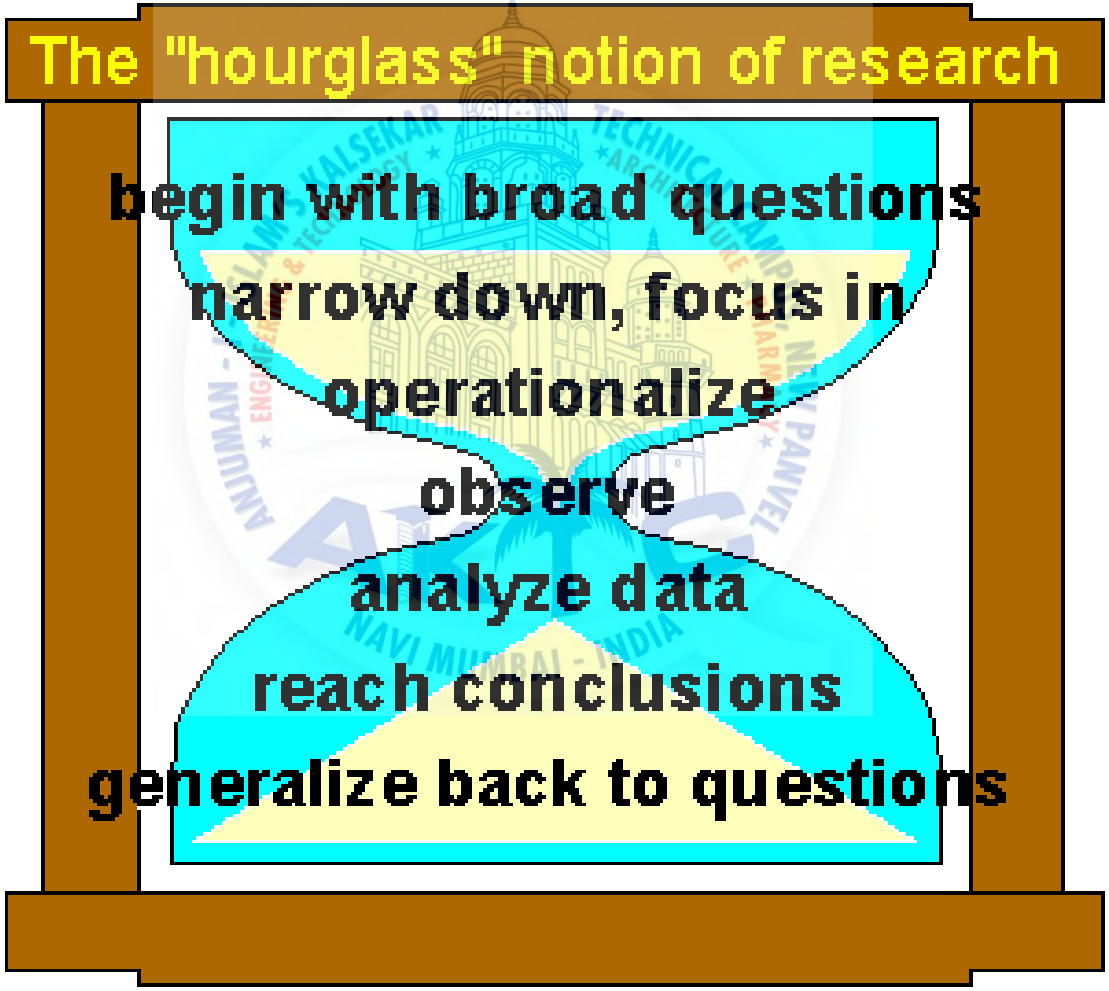
- Problems can range from open theoretical problems to evolutionary technology problems…
- Modeling complex theoretical problems…
- Modeling and building prototype systems…
- Mix of the above…
- A wide range of problems to choose from depending upon interests and abilities…

What it takes ?

- Requires drive and motivation.
- Requires HARD WORK at a consistent pace.
- Requires suitable background, creativity, and intelligence.
- More importantly, requires continuity of Thought Process

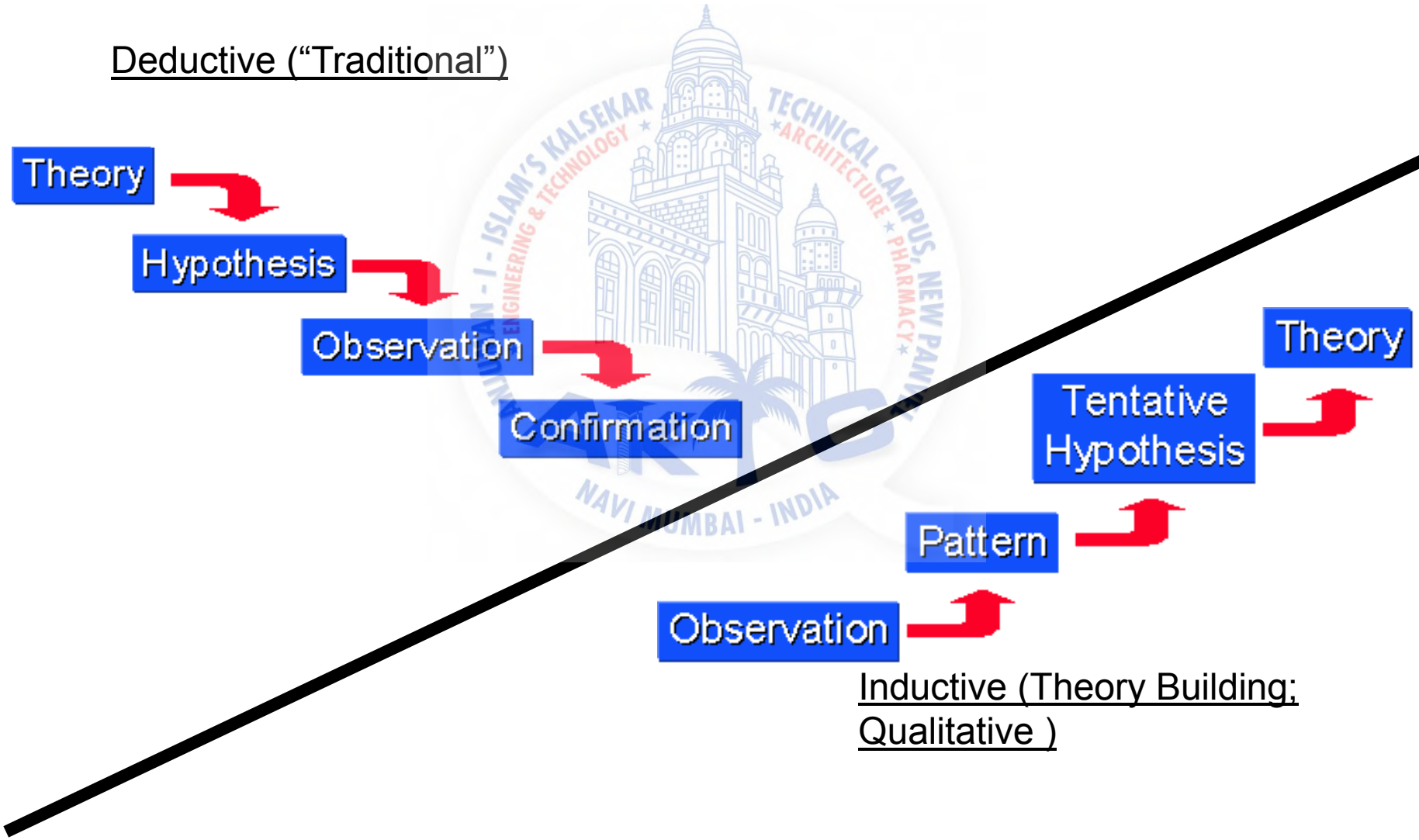
Flow of Research:
Top to Bottom Approach

Source: http://trochim.human.cornell.edu/kb/strucres.htm

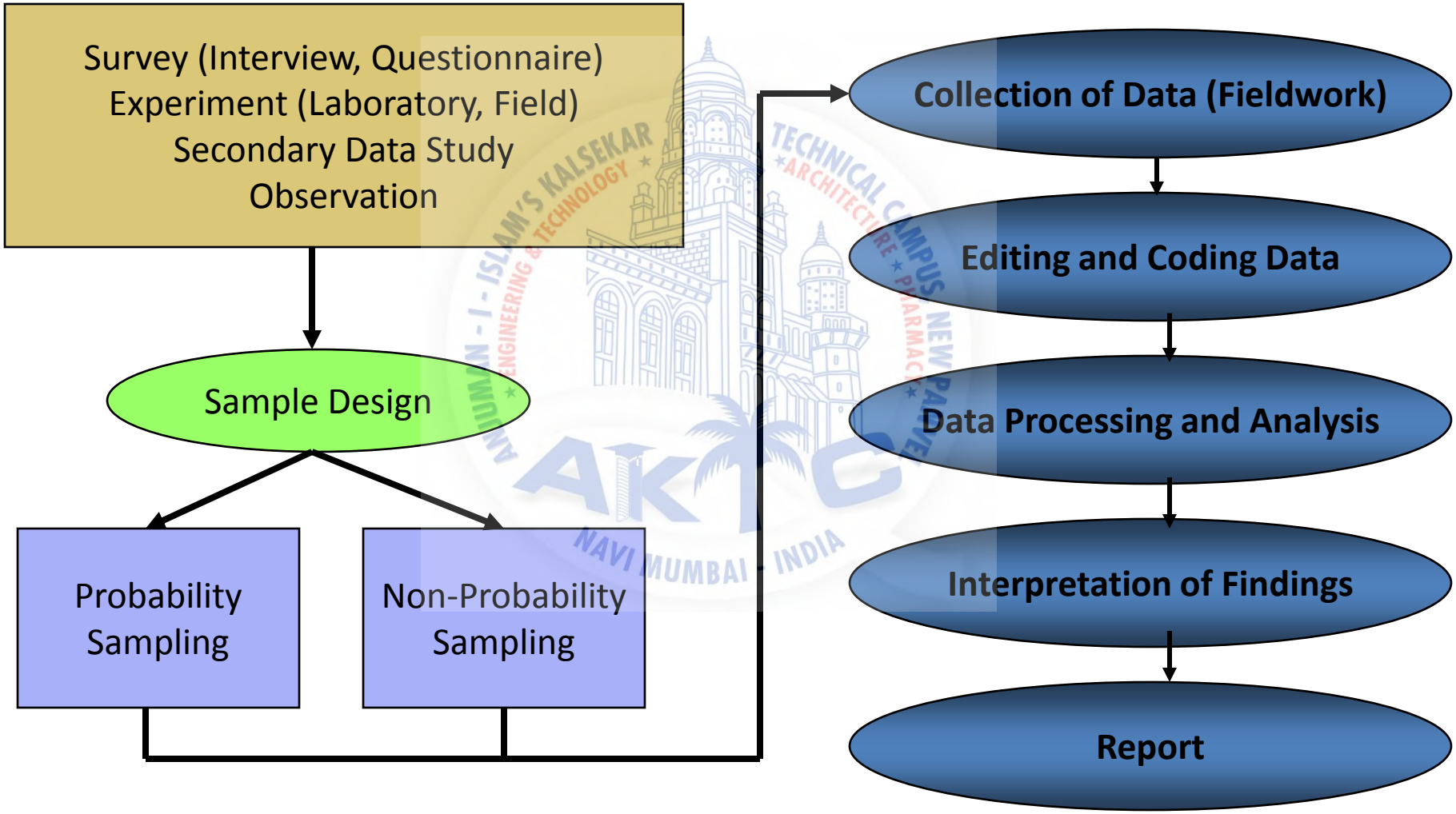


Flow of Research:
Inductive v. Deductive

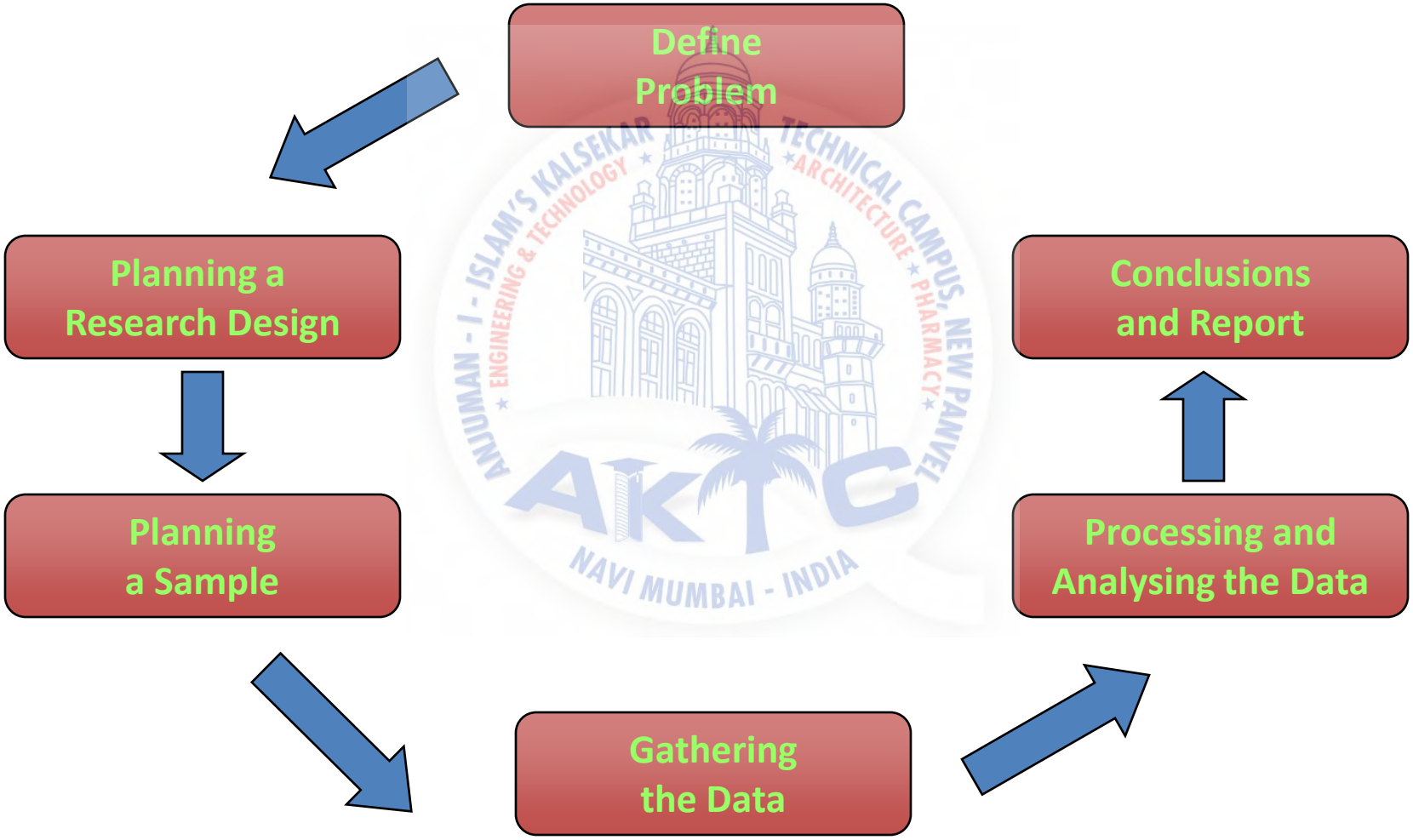
Source: http://trochim.human.cornell.edu/kb/dedind.htm



Research Process Flowchart



Stages in the Research Process



Video-1

Research essentially comprises of…

- Defining and redefining the problem
- Formulating hypothesis
- Collecting, organizing and evaluating data
- Making deductions and reaching conclusions
- Carefully testing the conclusions to determine whether they fit the hypothesis

Literature review…. An ongoing process…

Process of gathering information from various sources preferably journals and documenting it.

It helps:

1. To Identify flaws or gaps (missing links) in previous research providing justification for the study.

2. To identify gaps in techniques, processes and methods used.

3. To write motivation and scope of research work.

Contd…

4. Indirectly helps to finalize research problem.

5. Time consuming process (Requires continuous reading, patience to read and Continuous Process till research is over).

6. Refer some important standard previous thesis, worked on similar area.

7. Require to refer recent papers from leading international and national journals to work on research problem.

Data Collection and Analysis…

1. Scientific data collection…
2.Experimental data collection…
3.Observational study…
4. Sampling…
5.Statistical Survey…
6.Survey data collection…

Statistical Analysis requires…

1. To Know the authenticity of the data.
2. To find out errors (systematic) in data and gaps in data.
3.To select and perform appropriate method or technique to analyse data.

Research Methods

Type/Method	*Tests, Measurements*	*InterViews*	*Observations*	*Surveys*	*Documents*
Experimental	P		A		A
Quasi-Experimental	P		A		A
Causal-Comparative	P		A		A
Correlational	P		A		A
Descriptive	A	A		P	A
Evaluation	P	A	A	A	A
Ethnographic		A	P		A
Action		A	P	A	
Case Study		A	P	A	A

Research Techniques

1. Mathematical / Numerical/Experimental…
2. Software's / Charts / Graphs…
3. Programming or Coding…
3. Graphical methods…
4. Modeling…

Video-2

Thesis Writing

- When you are about to begin, writing a thesis seems a long and tedious process.
- Fortunately, it will seem less daunting once a couple of chapters done.
- Towards the end, will find yourself enjoying it.
- Like many tasks, thesis writing usually seems worst before it begin, so let us look at how you should make a start.

Organization of the Thesis

- Thesis shall be presented in a number of chapters, starting with Introduction and ending with Summary and Conclusions.

- Each of the other chapters will have a precise title reflecting the contents of the chapter.

- A chapter can be subdivided into *sections, subsections* so as to present the content discretely and with due emphasis.

Organization of the Thesis

- When the work comprises two or more mutually independent investigations, thesis may be divided into two or more parts, each with an appropriate title.
- However, the numbering of chapters will be continuous right through, for example Part 1 may comprise
- Chapters 2-5,
- Part Two, Chapters 6-9.

Typical Contents

- Chapter 4
- Chapter 5
- Chapter 6 Summary and Conclusions
  - 6.1 Summary
  - 6.2 Conclusions
  - 6.3 Research Contribution
  - 6.4 Scope for research work
- Appendix
- References
- List of Publications
- Acknowledgements

• Introduction

- ❖ Chapter 1 shall be Introduction. It shall justify and highlight the problem
- ❖ Define topic and explain the aim and scope of the work presented in thesis…
- ❖ Highlight the significant contributions from the investigation.
- ❖ What is the topic and why it is important? State the problem's as simple as you can.
- ❖ Introduction should be interesting. If you bore the reader here, then you are unlikely to revive his/her interest in the materials and methods section.
- ❖ Introduction should tell where the thesis is going flow of work done should maintain

Review of Literature

- This shall normally form Chapter 2 and shall present a critical appraisal of the previous work published in the literature pertaining to the topic of the investigation.
- The extent and emphasis of the chapter shall depend on the nature of the investigation.
- Where did the problem come from? What is already known about this problem? What other methods have been tried to solve it?

Review of Literature (Contd)

- When you start reading about a topic, should open a spread sheet file, or at least a word processor file, for your literature review.

- Write down the title, authors, year. volume and pages.

- Write a summary (anything from a couple of sentences to a couple of pages, depending on the relevance).

- In other columns of the spread sheet, add key words (your own and theirs) and comments about its importance.

Middle chapters

❖ The exact structure in the middle chapters will vary and establish some theory, to describe the experimental techniques.

❖ What was done on several different problems or different stages of the problem, and then finally to present a model or a new theory based on the new work.

❖ Due importance shall be given to experimental setups, procedures adopted, techniques developed, methodologies developed and adopted.

❖ Representative data in table and figures may, however, be included in appropriate chapters.

• Results and Discussions

- Penultimate chapter of the thesis, shall include a thorough evaluation of the investigation carried out and bring out the contributions from the study.
- Discussion shall logically lead to inferences and conclusions as well as scope for possible further future work.
- In most cases, results need discussion. What do they mean? How do they fit into the existing body of knowledge?
- Are they consistent with current theories? Do they give new insights?
- Do they suggest new theories or mechanisms?

• Summary and Conclusions

- ❑ Final chapter of the thesis. A brief report of the work carried out…
- ❑ Conclusions derived from the logical analysis presented in the results and discussions Chapter is presented and clearly enumerated..
- ❑ Scope for future work and research contribution stated lucidly in the last part of the chapter.

Abstract

- Abstract or summary summarizes appropriate headings, aims, scope and conclusion of the thesis. Examiners look here to find out whether it is new knowledge; and if so what?

- Summary or Abstract is most difficult part to write. Do not make the mistake of trying to write it first. Will waste time and get discouraged.

- Abstract should be written last.

- An abstract is a short summary of completed research. If done well, it makes the reader want to learn more about research.

.

• Appendix

- Detailed information, lengthy derivations, raw experimental observations etc. which shall be numbered in Roman Capitals (e.g." Appendix IV")…
- Material that should be in the thesis but break up the flow or bore the reader be included in Appendix...
- Important and original computer programs, too large data files be represented simply in the results chapters...
- Less important Pictures or diagrams of results may go to Appendix....

• Literature Cited

- Follow the Appendices, if any, otherwise after Summary and Conclusions chapter.
- Initials and full title of the article/monogram/book etc. given in addition to the journals/publishers, volume, number, pages (s) and year of publication…
- Citation from websites include the names(s) of author(s) (including the initials), full title of the article, website reference and when last accessed…
- Reference to personal communications, similarly, shall include the author, title of the communication (if any) and date of receipt…

Publications by the candidate

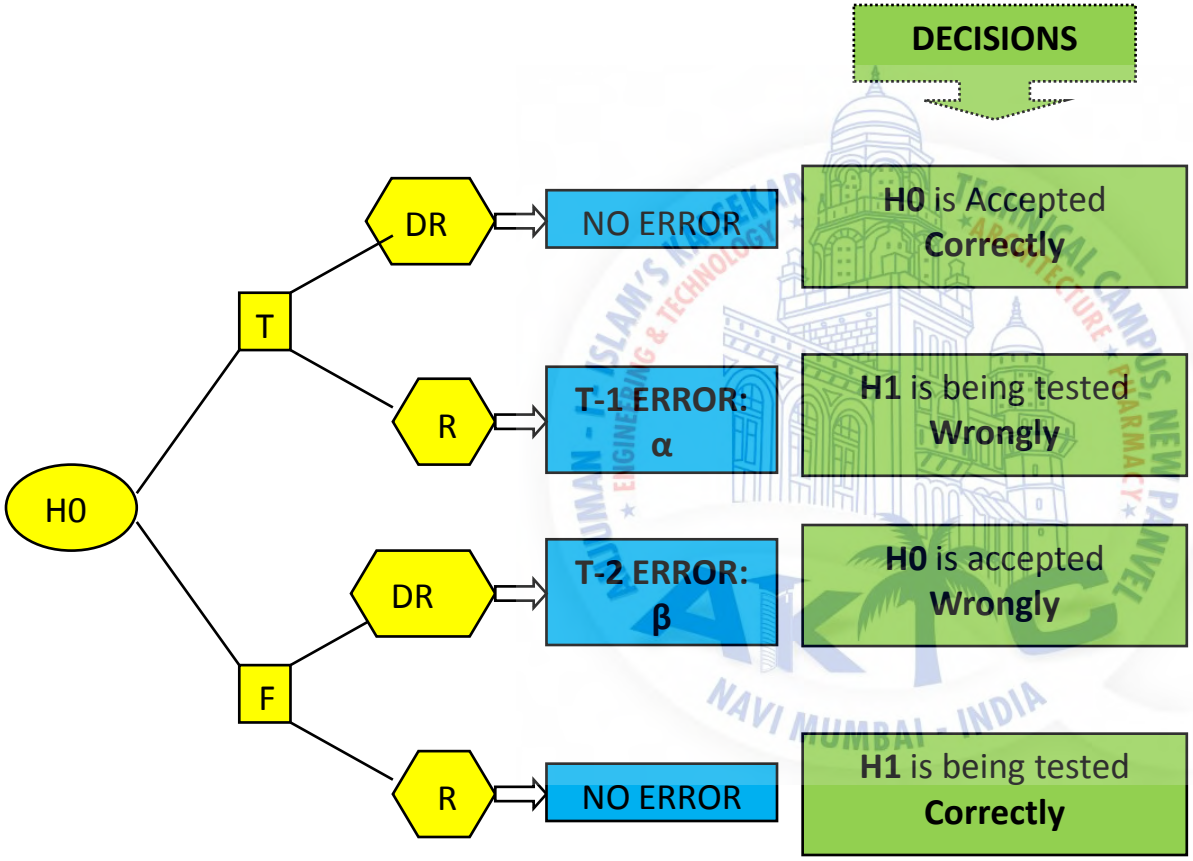
- Articles, technical notes etc. on the topic of the thesis published by the candidate may be separately listed after the literature cited. This may also be included in the contents.

- May also include reprints of his/her publications after the literature citation.

Acknowledgements

- Shall follow the citation of literature
- Advisor(s) and anyone who helped be included:
  - Technically (including materials, supplies)
  - Intellectually (assistance, advice)
  - Financially (for example, departmental support, travel grants)

TYPE-1 & TYPE-2 Error in Hypotheses



H0: Null Hypothesis

H1: Alternate / Researcher Hypothesis

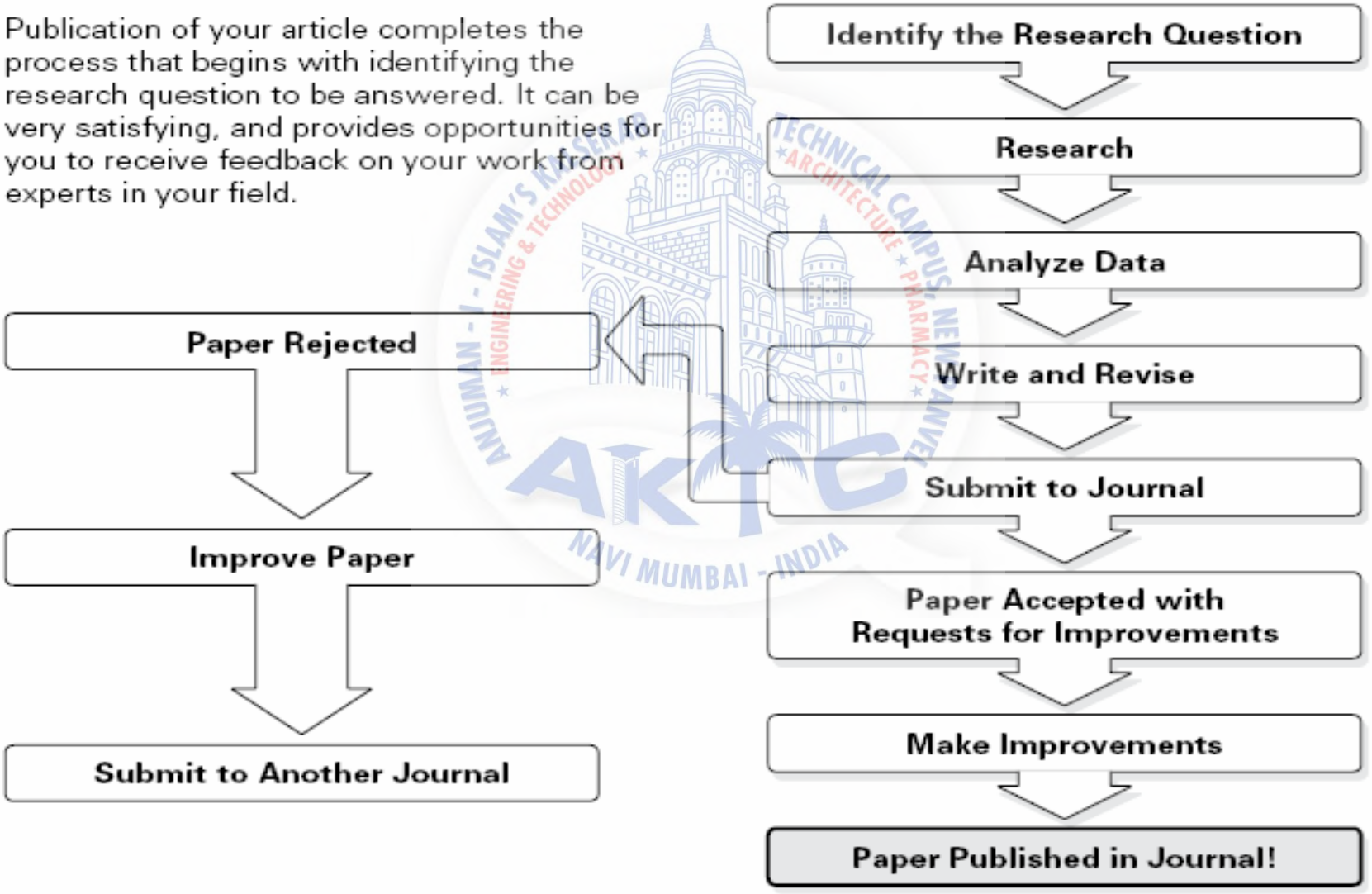
T : True ; F : False

R : Reject ; DR : Do not Reject

Technical Paper Writing (Publications)

The process at a glance

Publication of your article completes the process that begins with identifying the research question to be answered. It can be very satisfying, and provides opportunities for you to receive feedback on your work from experts in your field.



How to choose a Journal

Impact Factor-(which is important for him/her)

Editor, Editorial Board and quality of referring

Speed of publication

Writing a paper

- Always vital to read and follow the guidelines for the authors for the journal on the online site of the journal.

Structure of the paper

- Abstract-Summary of the work done
- Introduction-What question was asked in the research? Start with what you do in this paper?
- Methods and Methodology-How was it studied? What methods applied?
- Study area and analysis-Case study information details; statistical analysis
- Results and discussions-What was discovered? What do the findings means?
- Conclusions-
- Practical Significance if any
- References

A. Suitability of Topic

1. Is the topic appropriate for publication in this journal?
2. Is the topic important to colleagues working in the field?

B. Content

1. Is the paper technically sound? In no, why not?
2. Is the coverage of the topic sufficiently comprehensive and balanced?
3. How would you describe the technical depth of the paper?
4. How would you rate the technical novelty of the paper?

C. Presentation

1. How would you rate the overall organization of the paper?
2. Are the title and abstract satisfactory?
3. Is the length of the paper appropriate? If not, recommend how the length of the paper should be amended, including a possible target length for the final manuscript.
4. Are the symbols, terms, and concepts adequately defined?
5. How do you rate the English usage?
6. Rate the bibliography?

D. Overall Rating

1. How would you rate the technical content of the paper?
2. How would you rate the novelty of the paper?
3. How would you rate the "literary" presentation of the paper?
4. How would you rate the appropriateness of this paper for publication in this journal?

+ Section for Detailed Comments

- Publication – What does the reviewer look for?

Please indicate your confidence in your ability to referee th paper (%)

Is the paper original?

Is the paper novel?

Is the paper suitable for this journal? If no, why?

Is the paper technically sound?

Is the use of English clear and unambiguous?

Is the paper organised clearly to show what has been don

Please rate the paper by selecting one category from the following list

+ Section for detailed comments

Significance	1–5
Contribution	1–5
Originality/Novelty	1–5
Quality of presentation	1–5
Reviewer's expertise	1–5
Overall recommendation	

Finishing touch

- Title- should be concise and informative .Titles are often used in information-retrieval systems.
- Abstract-
  - Succinct summary of the content of the article.
  - Central and novel contribution.
  - A concise and factual abstract is required.
  - Should state briefly the purpose of the research,
  - Principal results and major conclusions.
- Keywords- Choosing meaningful keywords is crucial.
  - keywords will be used for indexing purposes.

Finishing touch

- Acknowledgements -Separate section at the end of the article before the references.

- Illustration and Tables-Good figures make a paper alive, and they communicate patterns in the data much better than the big tables.

- *Citation in text-*

Please ensure that every reference cited in the text is also present in the reference list (and vice versa).

- *Web references*

Full URL(Uniform Resource Locator) should be given and the date when the reference was last accessed. (DOI *(*digital object identifier), author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately.

Reference Style

❖ *Text:* All citations in the text should refer to:

❖ *Single author:* the author's name (without initials, unless there is ambiguity) and the year of publication;

❖ *Two authors:* both authors' names and the year of publication;

❖ *Three or more authors:* first author's name followed by "et al." and the year of publication.

❖ Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.

Reference

Examples: "as demonstrated (Allan, 1996a, 1996b, 1999; Allan and Jones, 1995). Kramer *et al.* (2000) have recently shown ...."

List: References should be arranged first alphabetically and then further sorted chronologically if necessary…

More than one reference from the same author(s) in the same year must be identified by the letters "a", "b", "c", etc., placed after the year of publication.

Reference

- Reference to a journal publication:

Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2000. The art of writing a scientific article. J. Sci. Commun. 163, 51–59.

- Reference to a book:

Strunk Jr., W., White, E.B., 1979. The Elements of Style, third ed. Macmillan, New York.

- Reference to a chapter in an edited book:

Mettam, G.R., Adams, L.B., 1999. How to prepare an electronic version of your article, in: Jones, B.S., Smith , R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281–304.

Submission checklist

✓One author has been designated as the corresponding author with contact details:

✓E-mail address

✓Full postal address

✓Telephone and fax numbers

✓All necessary files have been uploaded, and contain:

✓Keywords

✓All figure captions

✓All tables (including title, description, footnotes)

Further considerations

✓ Manuscript has been 'spell-checked' and 'grammar-checked'

✓ References are in the correct format for this journal

✓ All references mentioned in the Reference list are cited in the text, and vice versa

✓ Permission has been obtained for use of copyrighted material from other sources (including the Web)

✓ Color figures are clearly marked as being intended for color reproduction

Session II

MODELING TECHNIQUES

Modeling Techniques

Model

Simplified presentation of complex system. It represents the characteristics of the prototype...

Concept of Model

A simulation technique in which the mathematical relationships describing the interdependence of various parameters in the system are formulated is called a model

Steps in Modeling

- *Identification of the system-* The cause of underlying processes and their effects are identified.

- *Conceptualization of the system*:
  - The techniques that are to be used for the system are selected
  - Mathematical equations are formulated
  - Mathematics is to be translated to computer programs as algorithms.

- *Verification of the model*: With the series of known inputs and outputs, the model should be verified critically for all ranges of information.

- ***Implementation of the models***:

Accuracy of the reproduction of the model may be tested with several sets of the inputs and outputs.

Why models are necessary?

Measurement

Empirical Estimation

Rational Estimation

Mathematical Estimation

Prediction/Simulation

Types of Models

Iconic Model

Physical representation of the prototype
Experiments cannot be performed with theses models.
Example is a toy or car. The outside appears similar to prototype inside it is not the same as of prototype

Physical Model

Physical representation of the prototype
To a scale (may be step up scale or step down scale).
The material used in theses models is also same as that of prototype
Experiment can be conducted on the model and results can be related to the prototype

Analog Model

- These models represents the working conditions of the prototype (similar to physical model).

- Experiments are conducted in one entity and prototype results are interpreted

- Models are working models and there is no theoretical justification for the relationship between the input and output.

- *Deterministic Models-*
  - ❖The input or output data is definite one or determined value.
  - ❖Every set of variable states is uniquely determined by parameters in the model and by sets of previous states of these variables.
- *Stochastic model*
  - ➢ Stochastic means being or having a random variable. variable states are not described by unique values, but rather by probability distributions.
  - ➢ Estimating probability distributions of potential outcomes by allowing for random variation in one or more inputs over time.
  - ➢ Fluctuations observed in historical data for a selected period using standard time-series techniques.

Static vs. dynamic:

- Does not account for the element of time, while a dynamic model does.
- Dynamic models typically are represented with difference equations or differential equations.

***Discrete vs. Continuous*:**

✓A discrete model does not take into account the **function of time** and usually uses time-advance methods.

✓Continuous models typically are represented with f(t) and the changes are reflected over **continuous time** intervals.

Deductive Vs. inductive

- A deductive model is a logical structure based on a theory.
- An inductive model arises from empirical findings..

Conceptual Models

- Refer to models which are represented by concepts…
- Concepts which are formed after a conceptualization process in the mind…
- Conceptualization from observation of physical existence..
- Describe the system through the concept of probabilities or similarities.

Empirical models

- Physical process are neglected.
- Refers to any kind of (computer) modelling based on empirical observations.

System dynamics Model

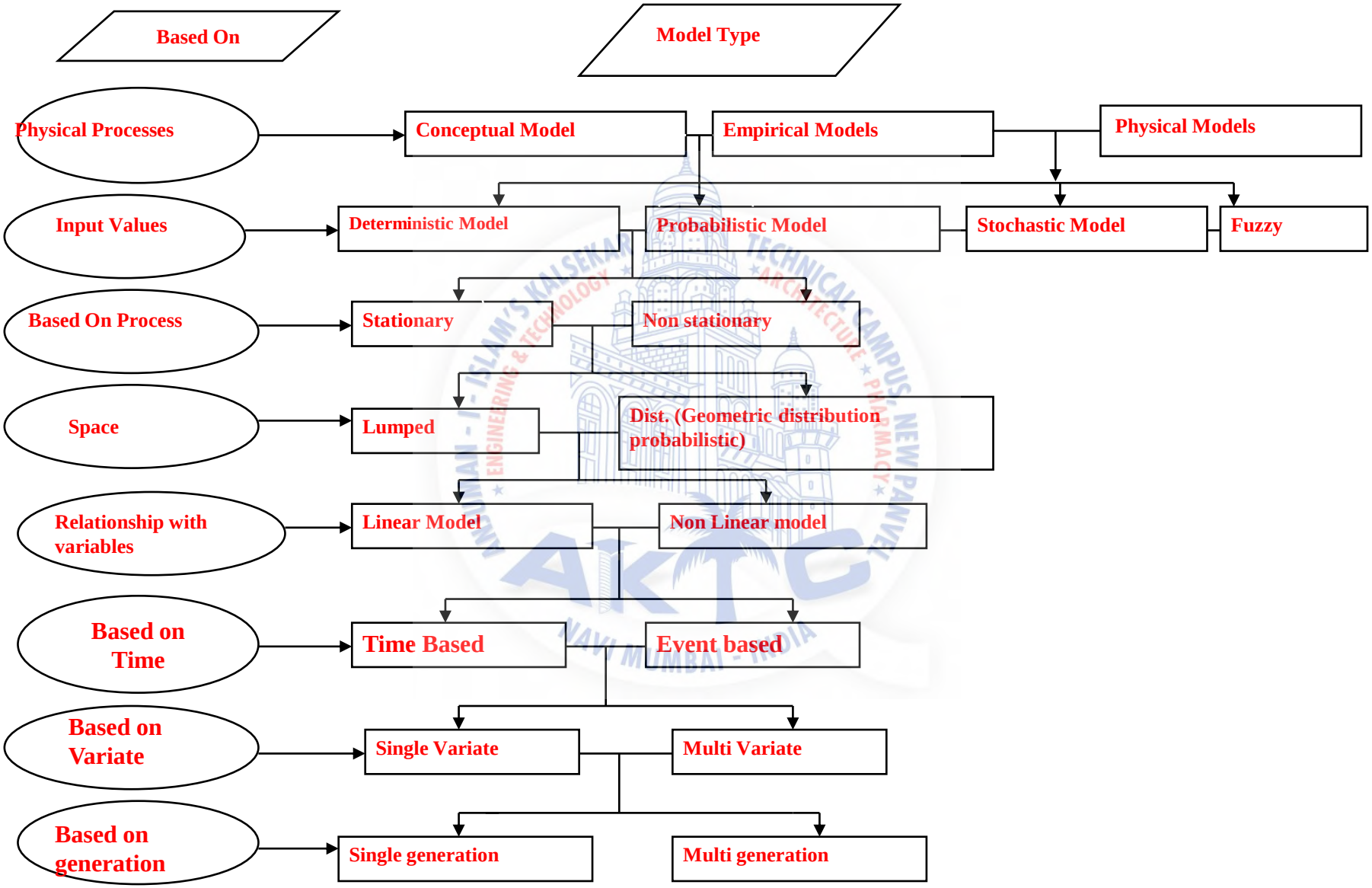
1. An approach to understanding the behaviour of complex systems over time.

2. Internal feedback loops and time delays that affect the behaviour of the entire system.

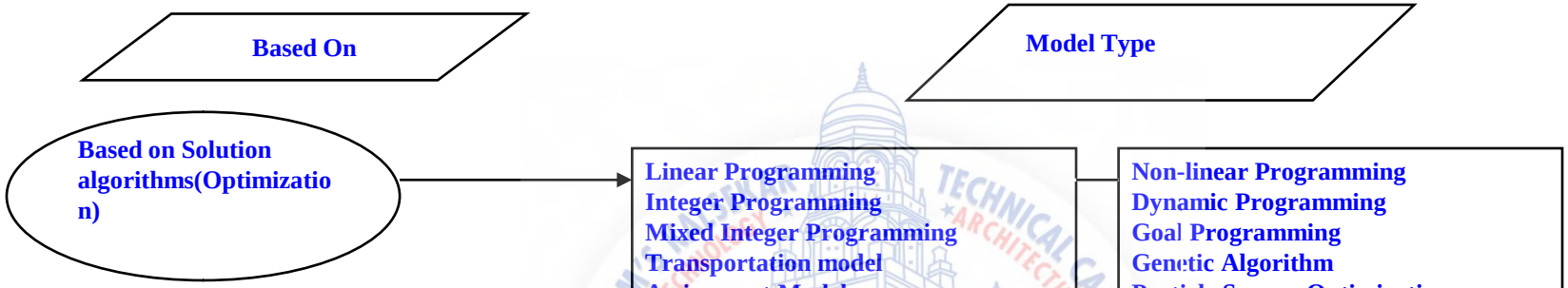
3. What makes using system dynamics different from other approaches to studying complex systems is the use of feedback loops.

4 Methodology and mathematical modeling technique for framing, understanding, and discussing complex issues and problems.

Types of Models



Modeling Techniques



Linear programming (LP, or linear optimization)

- Mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost).

- Mathematical Model for some list of requirements represented as linear relationships

- Linear programming is a specific case of mathematical programming (mathematical optimization).

Integer programming

- Mathematical optimization or feasibility program

- in which some or all of the variables are restricted to be integers

- Integer linear programming, which is also known as mixed integer programming when some but not all the variables are restricted to be integers.

NONLINEAR PROGRAMMING (NLP)

- Process of solving a system of equalities and inequalities, collectively termed constraints, over a set of unknown real variables.

- Maximized or minimized, where some of the constraints or the objective function are nonlinear.

- If the objective function is concave (maximization problem), or convex (minimization problem) and the constraint set is convex.

Dynamic programming

- Method for solving complex problems by breaking them down into simpler sub problems.
- It is applicable to problems exhibiting the properties of overlapping sub problems.
- To solve a given problem, need to solve different parts of the problem (sub problems), then combine the solutions of the sub problems to reach an overall solution.
- Seeks to solve each sub problem only once, thus reducing the number of computations.
- Useful when the number of repeating sub problems is exponentially large.

Goal programming –

- Branch of multiobjective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM).

- This is an optimization programme. It can be thought of as an extension or generalisation of linear programming to handle multiple, normally conflicting objective measures.

- Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimised in an achievement function.

Limitations of Above Techniques

- Traditional Techniques/Conventional techniques..
- Based on Assumptions..
- Not flexible-Problems closer to reality..
- Computational problem for higher dimensions issues..
- Curse of dimensionality (Lot of variables ,Direct and indirect)
- Fail to give solution for highly non-linear problems…

SWARM INTELLIGENCE TECHNIQUES

- Recent computational tools for systems optimization, which are gaining wide spread of popularity for solving large scale.
- Optimization problems and enabling improved decision making.
- Meta-heuristics algorithms; Population based random search techniques. Optimization problem by iterative search)
- Based on human intelligence cognition that derives from the interaction of individuals in social environment.
- Based on mimicking social behavior of insects or animals, in an effort to find optimum solution
- Describe the algorithms and distributed problem solvers, which were inspired by the collective behaviour of insect colonies and other animal societies.

TYPES OF SWARM INTELLIGENCE TECHNIQUES

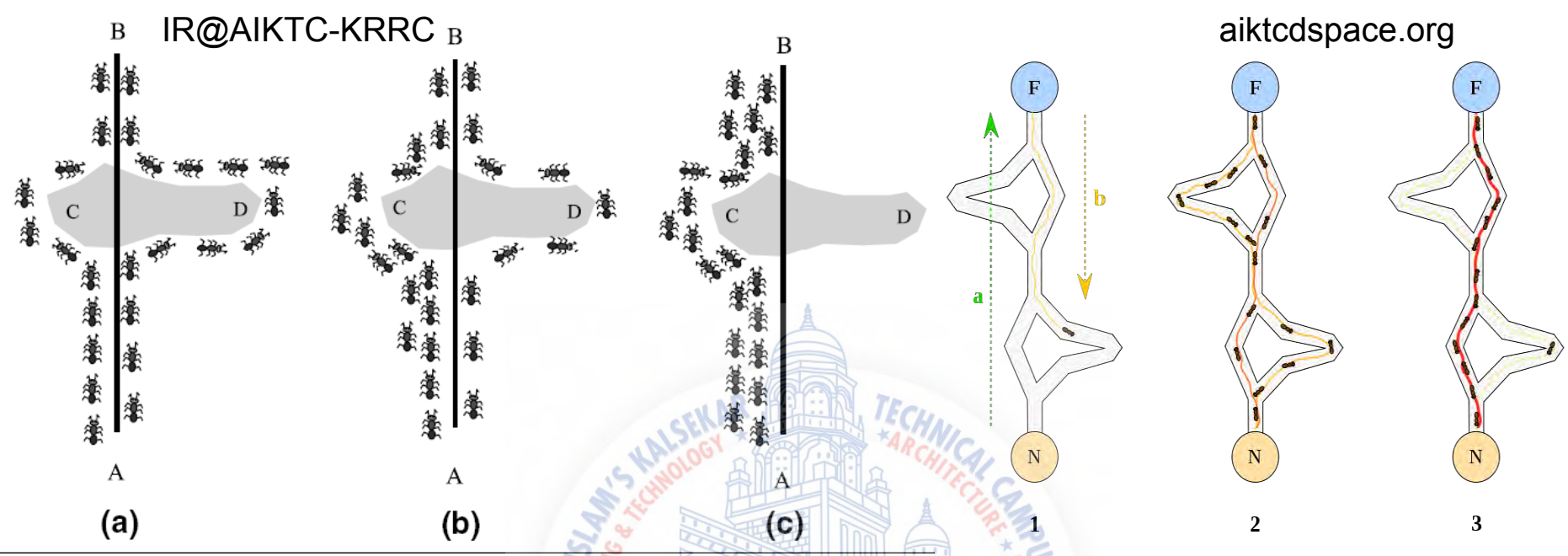
Ant Colony Optimization (ACO)

Particle Swarm Optimization (PSO)

- The ACO algorithm is basically inspired from the foraging search behaviour of real ants and their ability in finding shortest paths.

- Used for discrete combinatorial optimization tasks(operation research), exhibiting very interesting results in experiments as well as in real life applications.

- Population-based, general search technique for solution of difficult and complex problems, which is inspired by the pheromone trail laying and training behavior of real ant colonies.



EXAMPLE OF REAL A NTS FINDING THE SHORTEST PATH

(a)initially ants choose paths ACB and ADB with equal probability; (b) path ACB, being shorter, receives more pheromone with time; (c) more pheromone attracts more ants; hence eventually all ants will follow path ACB.

Particle swarm optimization (PSO)

- Population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behaviour of bird fish

- Optimize search-space according to simple mathematical formulae over the particle's position and velocity.

- Each particle's movement is influenced by its local best known position.

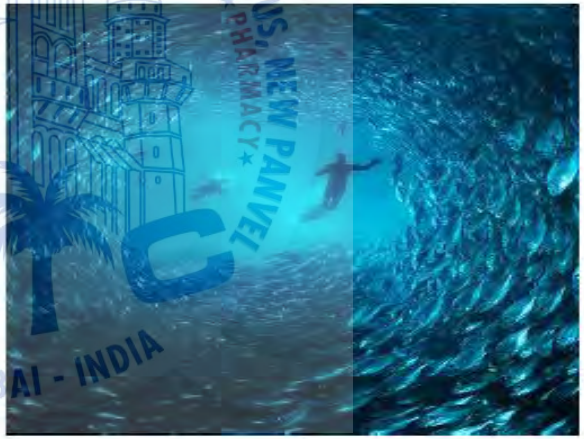
- Also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles.

- This is expected to move the swarm toward the best solutions.

Particle swarm optimization (PSO)

Particle swarm optimization: Origins

How can birds or fish exhibit such a coordinated collective behavior?



Other Modeling Techniques

- Interpretive Structural Modeling (ISM)
- Analytical Hierarchy Process (AHP)
- Analytical Network Process (ANP)
- System Dynamics (SD)

ANALYTICAL HIERARCHY PROCESS (AHP)

SYSTEM DYNAMICS RESEARCH APPROACH (SD)

Session III

SOFT COMPUTING TECHNIQUES

What is soft computing techniques?

- Tolerance for imprecision, uncertainty, approximate reasoning, and partial truth for obtaining low-cost solutions…
- Flexible information processing capability for handling real life ambiguous situations….
- Remarkable human ability of making rational decisions in an environment of uncertainty and imprecision….
- To find an acceptable solution at low cost by seeking an approximate solution to an imprecisely/ precisely formulated problem….

SOFT COMPUTING TECHNIQUES/ ARTIFICIAL INTELLIGENCE TOOLS IN ENGINEERING

- *Artificial Neural Networks (ANNs)*
- *Fuzzy Sytem*
- *Neuro-Fuzzy System*
- *Genetic Algorithm (GA)*
- *Genetic Programming (GP)*
- *Model Tree (MT)*
- *Support Vector Machines (SVM)*

ADVANTAGES OF SOFT COMPUTING TOOLS

- Model the process
- Improves the model performance
- Helps faster model development and calculation times
- Ability to handle large amount of data from dynamic and nonlinear systems
- Models based on human reasoning.
- Models can be linguistic
- Good in Practice

Artificial Neural Networks (ANNs)

Biological inspirations

- Some numbers…
  - The human brain contains about 10 billion nerve cells (neurons)
  - Each neuron is connected to the others through 10000 synapses
  - The human brain weighs only three pounds but is estimated to have about 100 billion cells.

- Properties of the brain
  - It can learn, reorganize itself from experience
  - It adapts to the environment
  - It is robust and fault tolerant

Biological neuron

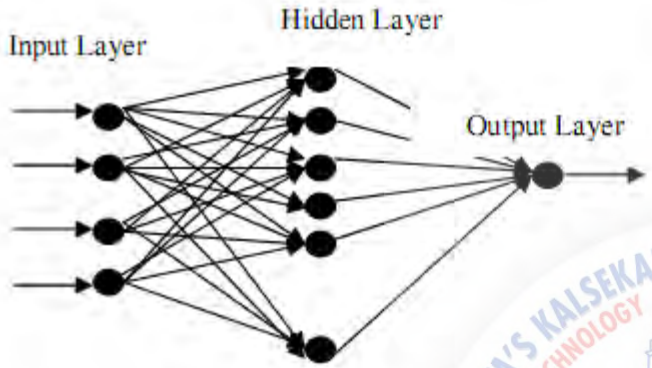


Fig. 1.a. Artificial Neural Network
Input, hidden & Output Layers

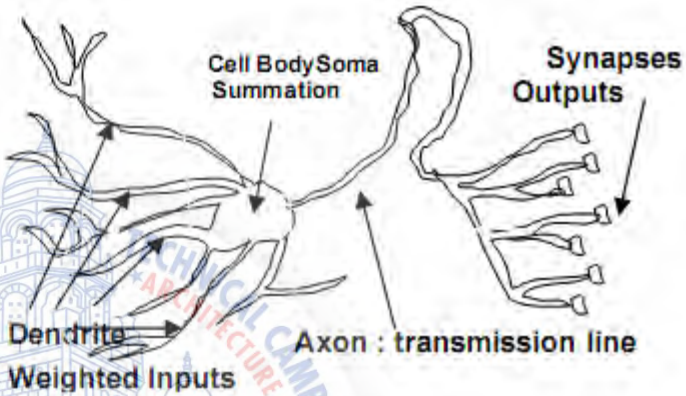


Fig. 1b. A Biological Neuron

- A neuron has
  - A branching input (dendrites)
  - A branching output (the axon)
- The information circulates from the dendrites to the axon via the cell body
- Axon connects to dendrites via synapses
  - Synapses vary in strength
  - Synapses may be excitatory or inhibitory

What can you do with an NN and what not?

- Artificial intelligence (AI) application that simulates the human brain's problem solving processes .

- Just as humans apply knowledge gained from past experience to new problems or situations, a neural network takes previously solved examples, looks for patterns in these examples, learns these patterns and develops the ability to correctly classify new patterns.

- Capable of self-organization and learning; concepts and patterns can be extracted directly from historical data without any complex mathematical formulas or algorithms.

- Does not require complex mathematical algorithms, only knowledge of the factors governing the process is needed.

Contd.

- No requirement of an explicit description of the problem. No need for a programmer.
- Adapts itself during a training period, based on examples of similar problems even without a desired solution to each problem.
- After sufficient training able to relate the problem data to the solutions, inputs to outputs, and it is then able to offer a viable solution to a brand new problem.
- Able to generalize or to handle incomplete data.
- Widely used as an effective approach for handling non-linear and noisy data
- Especially in situations where the physical processes relationships are not fully understood.

Applications off NNs

- **Classification**
  - Marketing: consumer spending pattern classification
  - Defence: radar and sonar image classification
  - Agriculture & Fishing: fruit and catch grading
  - Medicine: ultrasound and electrocardiogram image classification, medical diagnosis
- **Recognition and identification**
  - Computing and telecommunications: speech, vision and handwriting recognition
  - Finance: signature verification and bank note verification

Contd.

Assessment

- Engineering: product inspection monitoring and control
- Defence: target tracking
- Security: motion detection, surveillance image analysis and fingerprint matching

Forecasting and prediction

- Finance: foreign exchange rate and stock market forecasting
- Agriculture: crop yield forecasting
- Marketing: sales forecasting
- meteorology: weather prediction

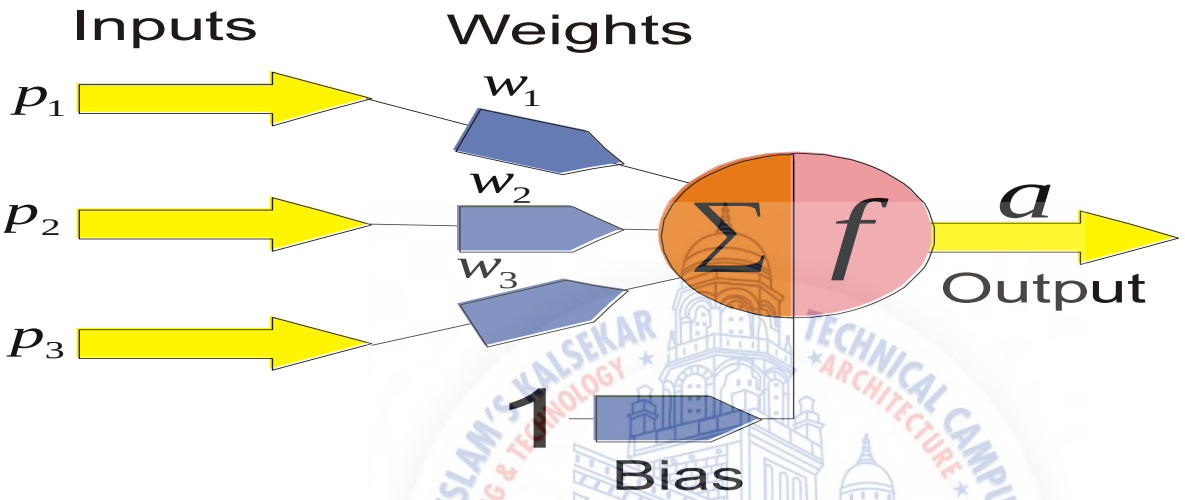
Who is concerned with NNs?

- Computer scientists want to find out about the properties of non-symbolic information processing with neural nets and about learning systems in general.
- Statisticians- As Flexible, Nonlinear regression and classification models.
- Engineers Signal Processing and automatic control.
- Cognitive scientists Thinking and consciousness (High-level brain function)...
- Neuro-physiologists To describe and explore medium-level brain function (e.g. memory, sensory system).
- Physicists To model phenomena in statistical mechanics and for a lot of other tasks

Characteristics of NNs

- Learning from experience: Complex difficult to solve problems, but with plenty of data that describe the problem
- Generalizing from examples: Can interpolate from previous learning and give the correct response to unseen data
- Adaptability: Adapts to a changing environment, if is properly designed
- Computational efficiency: Although the training off a neural network demands a lot of computer power, a trained network demands almost nothing in recall mode
- Non-linearity: Not based on linear assumptions about the real word

The Key Elements of Neural Networks



$$a = f(p_1 w_1 + p_2 w_2 + p_3 w_3 + b) = f\left(\sum p_i w_i + b\right)$$

- Each neuron within the network is usually a simple processing unit which takes one or more inputs and produces an output.
- At each neuron, every input has an associated weight which modifies the strength of each input.
- The neuron simply adds together all the inputs and calculates an output to be passed on.

Training methods

Supervised learning

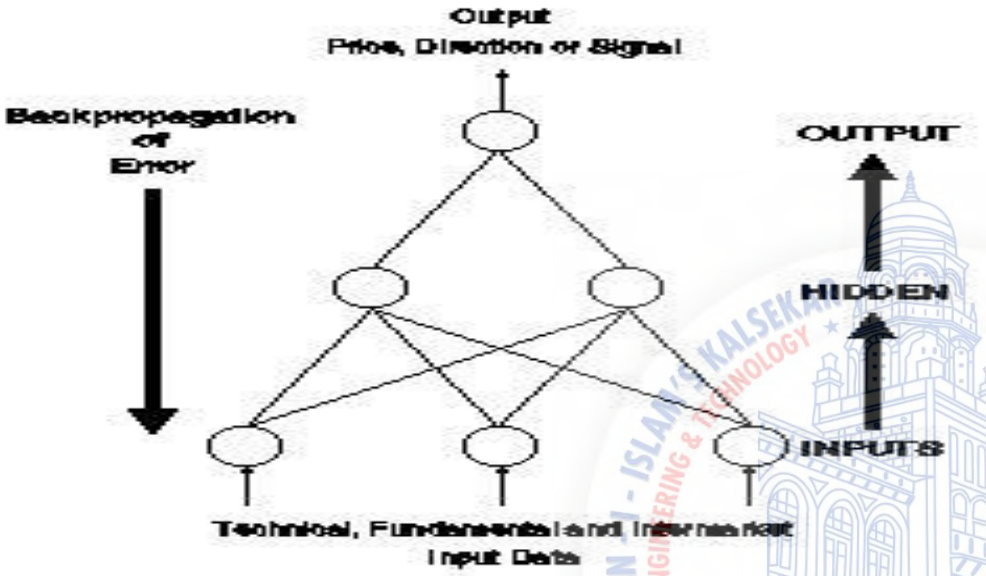
- In supervised training, both the inputs and the outputs are provided.
- The network then processes the inputs and compares its resulting outputs against the desired outputs.
- Errors are then propagated back through the system, causing the system to adjust the weights which control the network.
- The set of data which enables the training is called the training set. During the training of a network the same set of data is processed many times as the connection weights are ever refined.

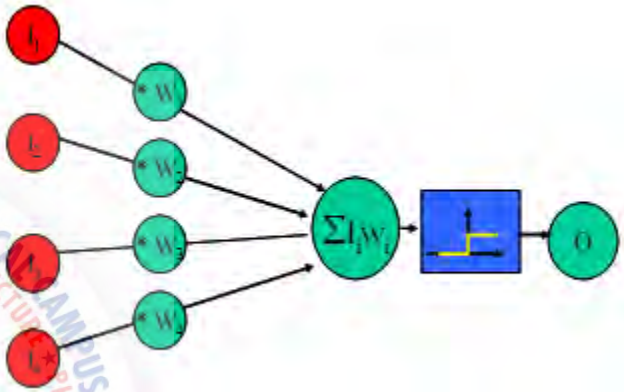
Unsupervised learning

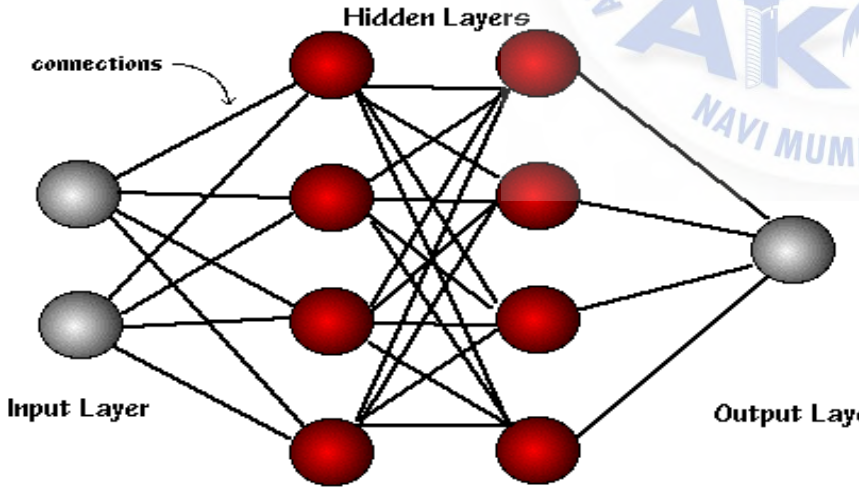
❖In unsupervised training, the network is provided with inputs but not with desired outputs.

❖ The system itself must then decide what features it will use to group the input data. This is often referred to as self-organization or adaption.

Feed forward neural Networks







Design Considerations

- What transfer function should be used?
- How many inputs does the network need?
- How many hidden layers does the network need?
- How many hidden neurons per hidden layer?
- How many outputs should the network have?
- How many training samples and testing samples?

No standard methodology to determinate these values. Even there is some heuristic points, final values are determinate by a trial and error procedure.

Fuzzy Logic

- Origin - dates back to 1965 since Lotfi Zadeh's introduction of the fuzzy-set theory.
- Boolean logic is extended to handle the concept of partial truth which implies that the truth takes a value between a completely true value and a completely false value.
- Partial truth can have values in linguistic variables like not very truth, more or less false etc. taking any values between 0 and 1, instead of taking a crisp value (0 or 1).
- The fuzzy logic approach is particularly a preferable tool for dealing with problems with uncertainties and imprecise information.

Applications

- Estimation, prediction, Control
- Approximate reasoning, pattern Recognition,
- Medical computing, robotics, optimization and industrial engineering.

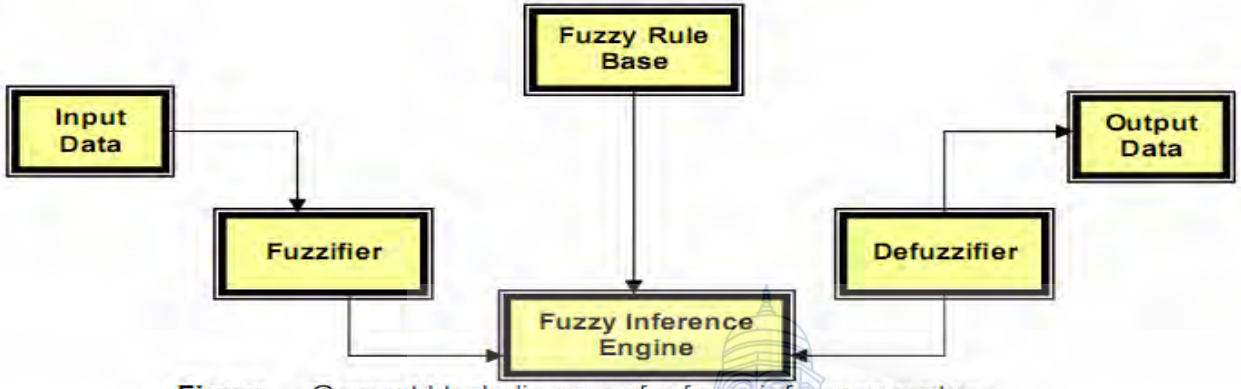
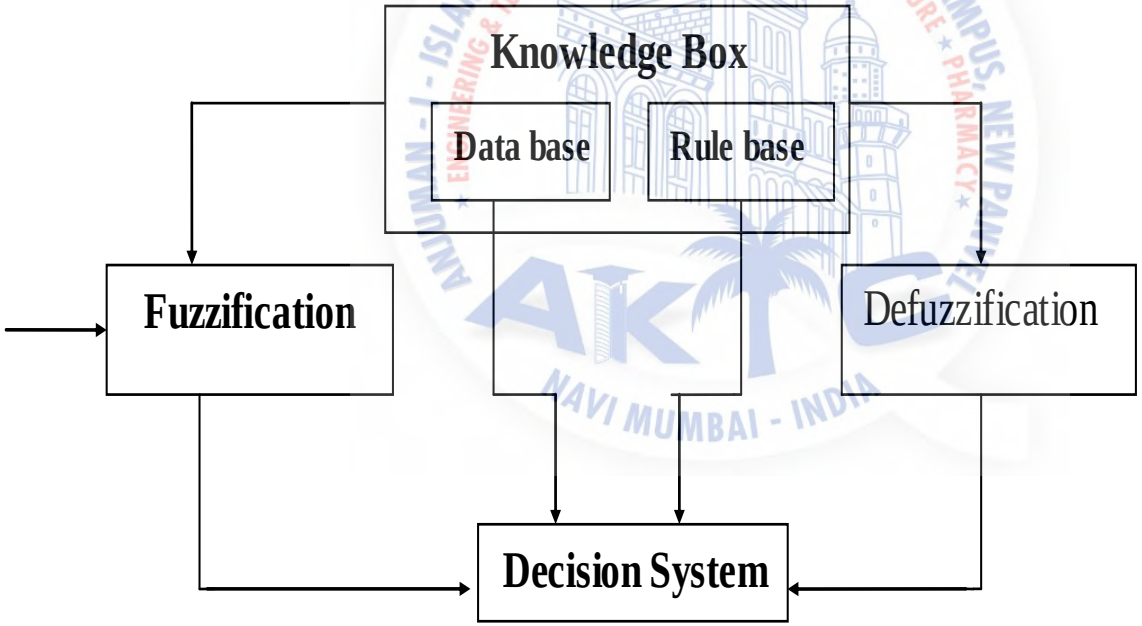


Figure General block diagram of a fuzzy inference system



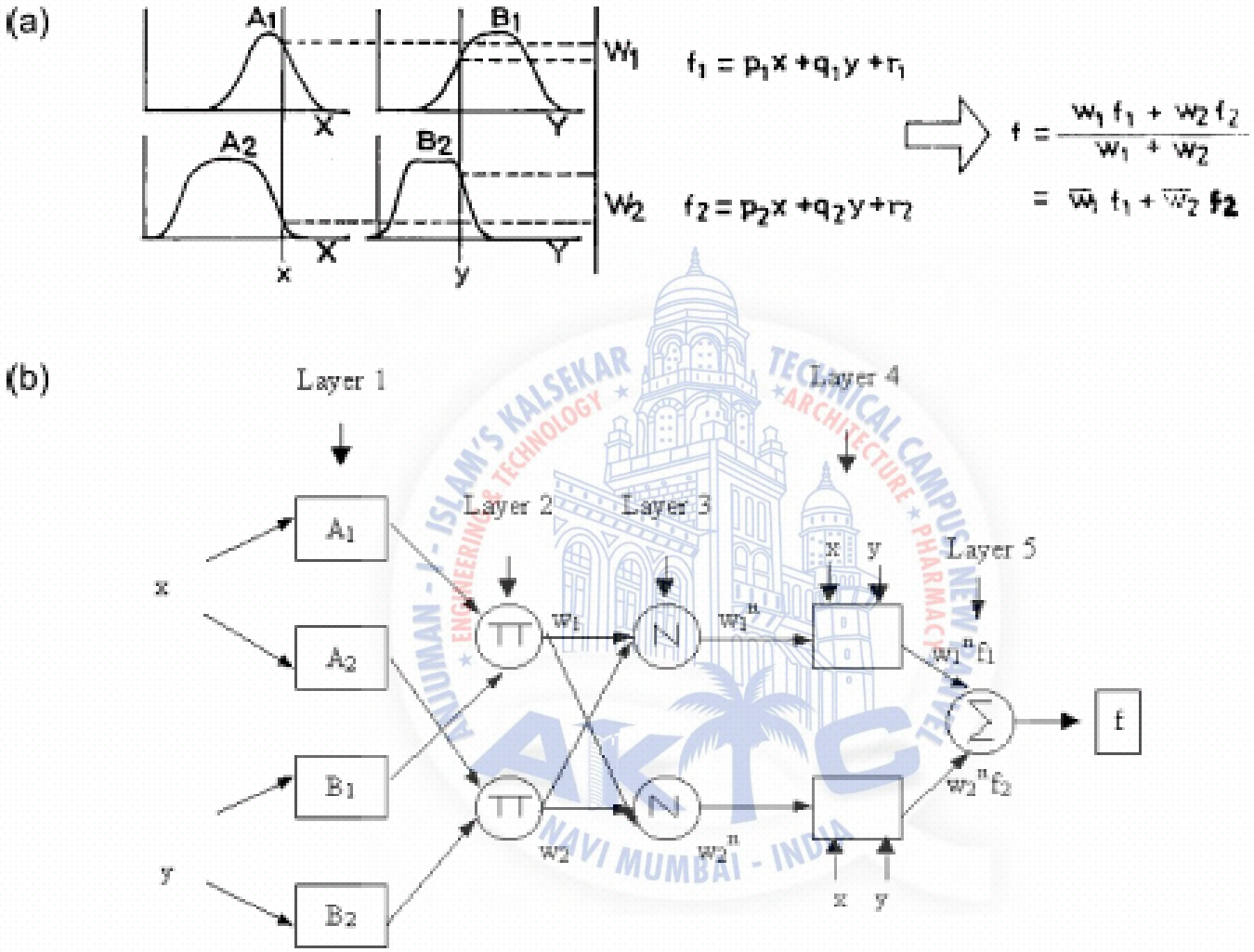
GENERAL STRUCTURE OF FUZZY INFERENCE SYSTEM

A comparative study between fuzzy systems and neural networks

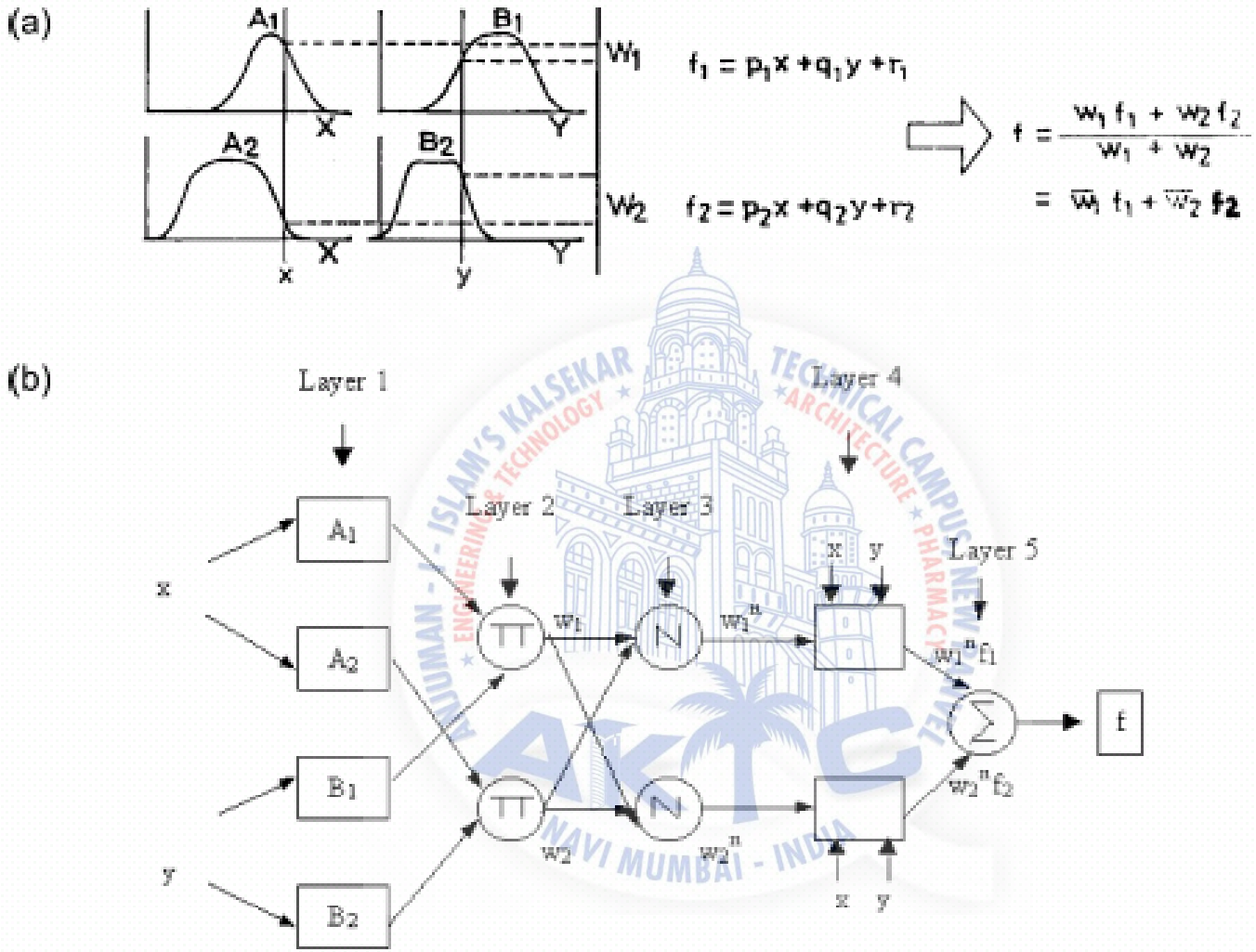
SKILLS		FUZZY SYSTEMS	NEURAL NETWORKS
Knowledge Acquisition	Inputs Tools	Human Experts Interaction	Sample sets Algorithms
Uncertainty	Information	Quantitative and Qualitative	Quantitative
Reasoning	Mechanism Speed	Heuristic Search Low	Parallel computations High
Adaptation	Fault tolerance learning	Low Induction	Very High Adjusting Synaptic weights
Natural language	Implementation Flexibility	Explicit High	Implicit Low

NEURO FUZZY

- ANN recognize the patterns and adapt themselves to cope with changing environment. Tolerance for noisy data.
- Fuzzy inference system that incorporates human knowledge and perform interfacing and decision making. Tolerance for imprecision of data.
- Neuro fuzzy get benefits of both ANN and fuzzy and remove the individual disadvantages of on combining them on common features.
- A combination can constitute an interpretable model that is capable of learning and can use problem-specific prior knowledge.



(a) Fuzzy inference system (b) Equivalent ANFIS architecture (Nayak et al 2004)



(a) Fuzzy inference system (b) Equivalent ANFIS architecture (Nayak et al 2004)

The Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics.

Genetic algorithms (GAs) are a part of Evolutionary computing, a rapidly growing area of artificial intelligence. GAs are inspired by Darwin's theory about evolution - "survival of the fittest".

GAs represent an intelligent exploitation of a random search used to solve optimization problems.

GAs, although randomized, exploit historical information to direct the search into the region of better performance within the search space.

In nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones.

Optimization Algorithms

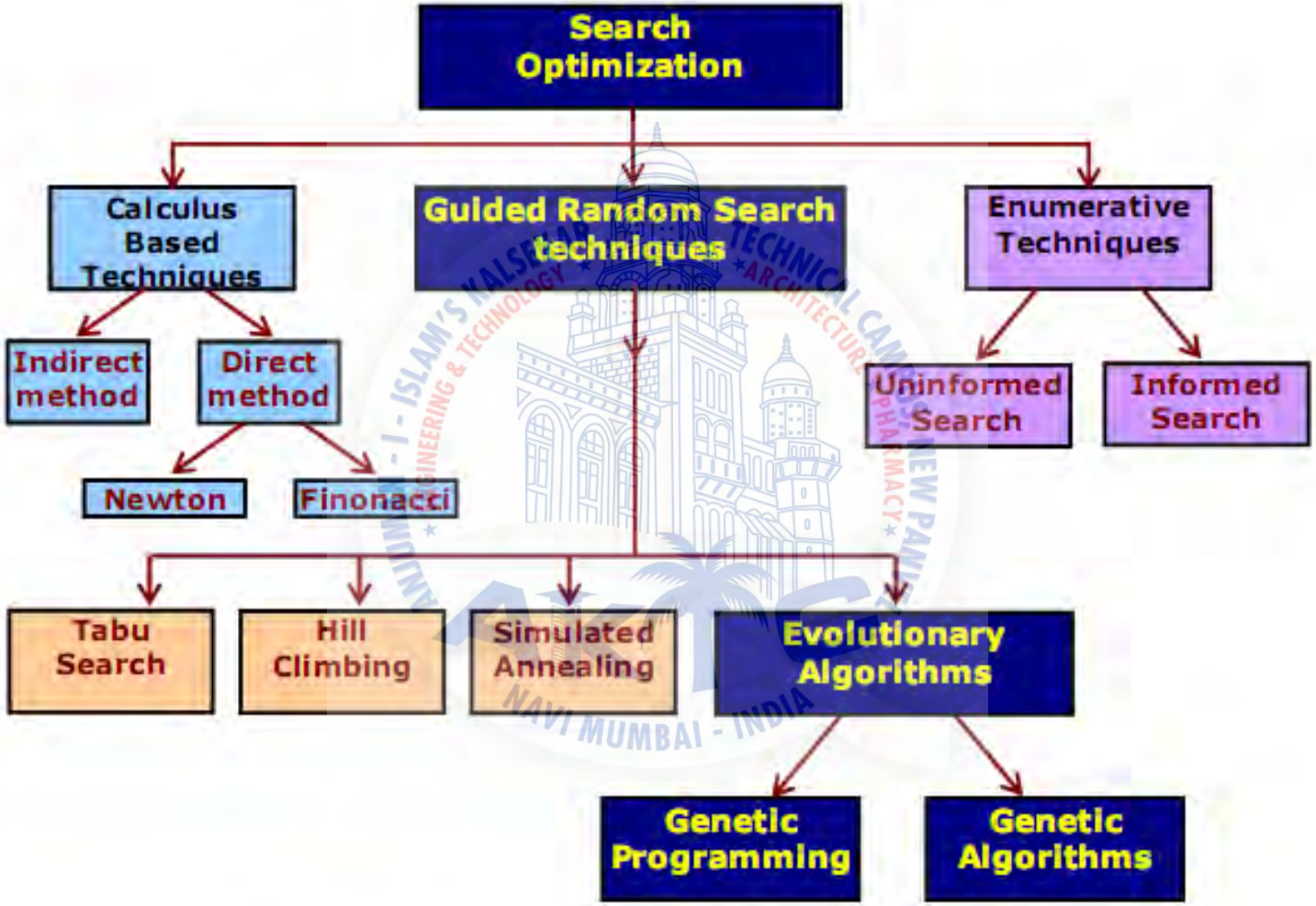


Fig. Taxonomy of Search Optimization techniques

Components of a GA

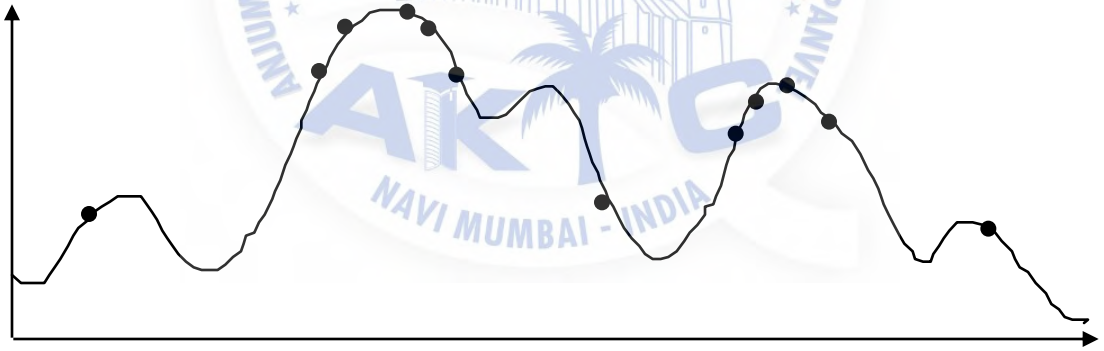
- Encoding technique (*gene, chromosome*)
- Initialization procedure *(creation)*
- Evaluation function *(environment)*
- Selection of parents *(reproduction)*
- Genetic operators *(mutation, recombination)*
- Parameter settings *(practice and art)*

Simple Genetic Algorithm

```
{
    initialize population;
    evaluate population;
    while Termination CriteriaNotSatisfied
    {
        select parents for reproduction;
        perform recombination and mutation;
        evaluate population;
    }
}
```

An Abstract Example

Distribution of Individuals in Generation 0



Distribution of Individuals in Generation N

Benefits of Genetic Algorithms

- Concept is easy to understand
- Modular, separate from application
- Supports multi-objective optimization
- Good for “noisy” environments
- Always an answer; answer gets better with time
- Inherently parallel; easily distributed

Some GA Application Types

Domain	Application Types
Control	gas pipeline, pole balancing, missile evasion, pursuit
Design	semiconductor layout, aircraft design, keyboard configuration, communication networks
Scheduling	manufacturing, facility scheduling, resource allocation
Robotics	trajectory planning
Machine Learning	designing neural networks, improving classification algorithms, classifier systems
Signal Processing	filter design
Game Playing	poker, checkers, prisoner‟s dilemma
Combinatorial Optimization	set covering, travelling salesman, routing, bin packing, graph colouring and partitioning

GENETIC PROGRAMMING

A Brief Overview

GENETIC PROGRAMMING

- It starts from a high level statement, “what needs to be done”, and automatically create a computer program to solve a problem
- It is a branch of AI, which evolve computer model automatically by methods of natural selection
- Principle of GP is rooted in GA
- It works best when
  - There is no ideal solution
  - Variables are changing, constantly

GENETIC PROGRAMMING

- Genetic programming is a branch of genetic algorithms.
- The main difference between genetic programming and genetic algorithms is the representation of the solution.
- Genetic programming creates computer programs in the lisp (LISt Processing) or scheme computer languages as the solution.
- Genetic algorithms create a string of numbers that represent the solution.

Genetic programming, uses four steps to solve problems

- Generate an initial population of random compositions of the functions and terminals of the problem (computer programs).

- Execute each program in the population and assign it a fitness value according to how well it solves the problem

- Create a new population of computer programs...

i) Copy the best existing programs..
ii) Create new computer programs by mutation.
iii) Create new computer programs by crossover (reproduction)...

- The best computer program that appeared in any generation, the best-so-far solution, is designated as the result of genetic programming

MODEL TREE (MT)

- Machine learning technique based on idea of splitting the input into sub areas and building “local” linear regression models in each of them.

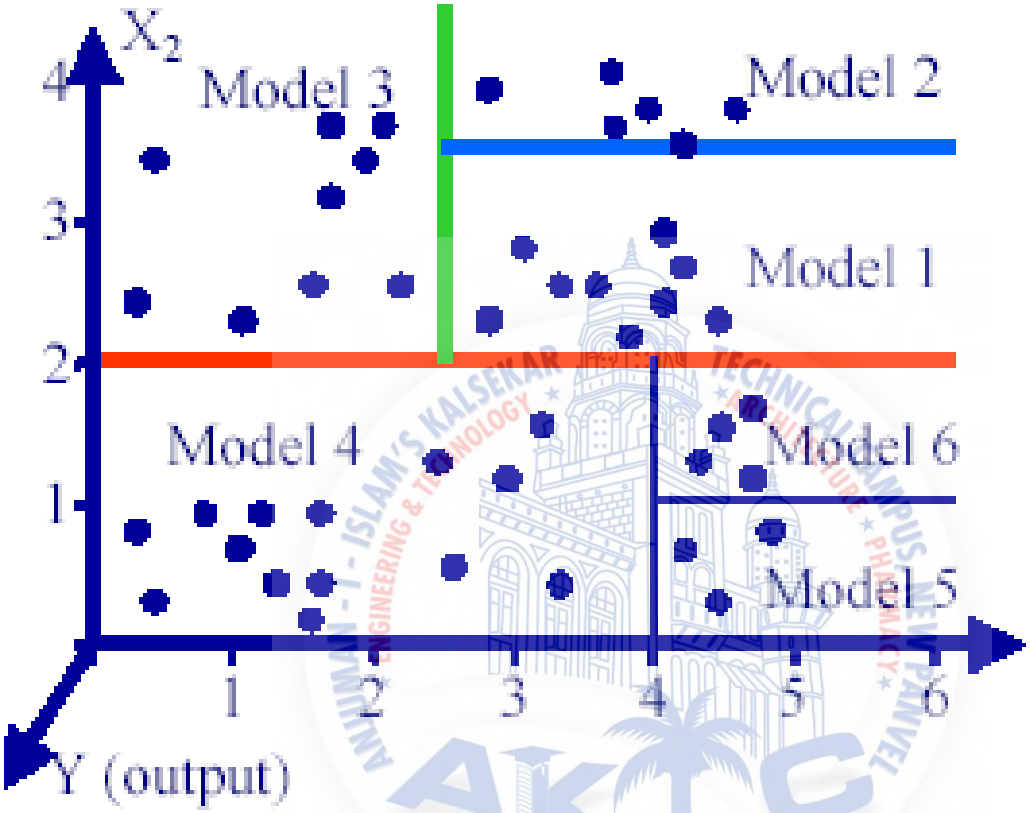
- Data driven algorithm (Quinlan, 1993) built of a rule-based predictive structure using a top–down induction approach.

- Follows that of decision tree and has multivariate linear regression models at the leaf nodes

- Combination of piecewise linear models each of which is suitable for a particular domain of input space

- Algorithm breaks the input space of the training data through nodes or decision points to assign linear model

- Model trees have several advantages since it can be trained faster and has transparent results, which are easily understood.



Splitting the input space X1 x X2 by M5 model tree algorithm; each model is a linear regression model *y* = a0 + a1x1 + a2x2

SUPPORT VECTOR MACHINES

- The foundation of the subject of support vector machine (SVMs) has been developed by Vapnik

- Machine learning paradigm which is firmly based on the theory of statistical learning

- Interesting Property of this approach is an approximate implementation of a structural risk minimization.

- The standard SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the input, making the SVM a non-probabilistic binary linear classifier.

eBooks

- Introduction to Methods of Applied Mathematics or Advanced Mathematical Methods for Scientists and Engineers.
- Applied Finite Element Analysis second analysis-John Wily and SonsO C.Zienkiewicz and R L Taylor.
- „C"the Complete Reference-Herbert Schildt
- Computational Engineering-Introduction to Numerical Method
- Numerical method in Engineering with MATLAB –Jaan Kiusalaas
- Pipe line rules of thumb-Handbook-E W Mc Allister

Soft computing tools

- Artificial Neural Networks (ANNs)
- Neuro-Fuzzy System
- Genetic Programming (GP)

Performance Measures

- Pearson's coefficient of correlation (R)
- Root Mean square error (RMSE)
- Nash-Sutcliffe Efficiency (E)
- Coefficient of determination (R^2)
- Akaike information criterion (AIC)
- Bayesian information criterion (BIC)
- **Percentage mean error in estimating peak flow (%MF)**