Unit I: Introduction to Research Problem

Dr. Ayush Kumar Agrawal

SoCS,
UPES

2025

What is Research?

- Systematic and scientific investigation
- Objective: Discover new facts, verify old ones, analyze relationships
- Types: Fundamental, Applied, Exploratory

Key Elements of Research

- Problem identification
- Data collection and analysis
- Hypothesis formation
- Result interpretation

Class Activity

- Think-Pair-Share: "What real-world problem would you like to solve?"
- Identify if it qualifies as a research problem

Why Research Matters

- Basis of advancement in technology and knowledge
- Helps in policy making, industrial innovation, academic growth
- Important in Computer Science for: algorithms, AI, HCI, etc.

Objectives of Research

- To find answers to questions through scientific methods
- To explain phenomena, establish relationships
- To test and validate existing theories

Characteristics of a Good Research Problem

- Clear and concise statement
- Researchable and feasible
- Relevant and original
- Offers scope for data collection and analysis

Example: Weak vs. Strong Problem

- Weak: "AI is interesting."
- Strong: "How can reinforcement learning optimize traffic signals in smart cities?"

Common Errors in Research Problem Selection

- Ambiguity or vagueness
- Too broad or too narrow in scope
- Lack of relevance or feasibility
- Ignoring prior art (existing research)

How to Avoid Errors?

- Perform literature review
- Consult experts or guides
- Conduct pilot studies
- Align with objectives and available resources

Scope of Research

- Defines limits and boundaries of study
- Prevents deviation from objectives
- Examples of narrow vs. broad scope

Defining Boundaries

- Time frame
- Geographic location (if applicable)
- Target population or dataset
- Tools or technologies used

Summary of Slide 2 - 12

- Introduced fundamentals of research
- Explored how to identify and refine a research problem
- Discussed errors and how to avoid them
- Understood setting boundaries for meaningful work

Discussion Questions

- What makes a research problem "worthy" of investigation?
- Why do many research efforts fail to make impact?
- Can a good problem exist without proper scope definition?

Research Objectives

- Set the direction and purpose of your research
- Help to define scope and methodology
- Provide focus and coherence

SMART Objectives

- **S**pecific: Clear and precise
- **M**easurable: Can be evaluated
- **A**chievable: Realistic and possible
- **R**elevant: Aligned with problem
- **T**ime-bound: Defined within timeframe

Activity: Write Your SMART Objective

- Ask each student to write a SMART objective for their selected topic
- Peer review and feedback

Sources of Research Problems

- Literature reviews and gaps
- Industrial problems and real-world needs
- Emerging trends and technologies
- Academic coursework and past projects

Example Sources

- Surveys of recent publications
- Patent and research databases
- Industry white papers
- Competitive research proposals

Identifying Research Problems

- Brainstorming sessions
- Interviews with domain experts
- Observing user pain-points in systems
- Comparative studies of similar works

Steps for Identification

1. Explore the domain broadly
2. Narrow it down through reading
3. Formulate question(s)
4. Validate feasibility and novelty

Types of Research Approaches

- **Exploratory**: Discover patterns, new ideas
- **Descriptive**: Describe characteristics/facts
- **Analytical**: Analyze existing information

Exploratory vs. Descriptive

- Exploratory: Often used in early-stage research
- Descriptive: Structured, uses surveys/metrics
- Choose based on nature of the research question

Theoretical vs. Empirical Research

- **Theoretical**: Abstract models, logic, proofs
- **Empirical**: Based on observation/experiments
- CS Examples: Algorithm analysis vs. performance benchmarking

Comparison Table

Criteria	Theoretical	Empirical
Basis	Logical deduction	Observation/data
Example	Complexity analysis	System benchmarking
Tools	Mathematics, models	Experiments, simulators

Discussion Prompt

- Can a research problem benefit from both theoretical and empirical methods?
- When should each be used?

Types of Data

- **Primary Data**: Collected directly (e.g., surveys, experiments)
- **Secondary Data**: Existing sources (e.g., journals, logs, repositories)
- **Qualitative vs Quantitative**: Narratives vs numerical values
- Choosing data types based on research goals

Examples of Data Sources

- Primary: Interviews, sensor readings, usage logs
- Secondary: GitHub datasets, Kaggle, IEEE articles, government data

Data Collection Tools

- Questionnaires & Online Forms (Google Forms, Typeform)
- Observation Logs & Experiments
- System Monitoring Tools (e.g., Wireshark, PerfMon)
- Web scraping (Python - BeautifulSoup, Selenium)

Data Collection Guidelines

- Maintain consistency and structure
- Ensure validity and reliability
- Ethical considerations and consent
- Minimize bias and errors

Data Analysis Approaches

- **Descriptive**: Mean, median, mode, standard deviation
- **Inferential**: Hypothesis testing, confidence intervals
- **Visual**: Charts, plots, heatmaps (Python: matplotlib, seaborn)

Data Interpretation

- Extracting insights and patterns
- Validating hypotheses
- Connecting results to research objectives
- Addressing outliers and anomalies

Research Instrumentation

- Tools, hardware, software used for data collection and analysis
- Examples: sensors, simulators, benchmarking suites
- Custom tools for robotics, networks, AI
- Importance of calibration and repeatability

Instrumentation in CS Domains

- IoT: Arduino, Raspberry Pi, NodeMCU
- Networks: Packet sniffers, traffic analyzers
- ML: Jupyter, TensorFlow profiling tools

Week Recap

- Learned about types and sources of data
- Tools for collection and analysis
- Use of instrumentation in computing research
- Interpretation of results with case illustrations

Case Study: Smart Irrigation System

- Data: Soil moisture, temperature sensors
- Collection: NodeMCU + DHT11 + cloud logging
- Analysis: Python scripts, thresholding, water usage
- Outcome: Reduced water wastage, optimized timing

Class Discussion

- Choose a domain: ML, IoT, Networks, etc.
- Identify a tool/instrument and its purpose
- Share how it can support a research question