ResearchMethods and Methodologies

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Outline

- Research Basics
  - What Research Is and Is Not ?
  - Research – Step by Step Process
  - Research Projects
- Research Methodologies
  - Research Process
  - Quantitative versus Qualitative Research
- Specific Research Areas in CSE
- Conclusion
- References

WhatResearch Is?

- The systematic process of collecting and analyzing information (data) in order to increase our understanding of the phenomenon about which we are concerned or interested.

WhatResearch IsNot ?

- **Research isn’t information gathering**
  - Gathering information from resources such as books or magazines isn’t research.
  - No contribution to new knowledge.
- **Research isn’t the transportation of facts**
  - Merely transporting facts from one resource to another doesn’t constitute research.
  - No contribution to new knowledge although this might make existing knowledge more accessible.

Research – Stepby StepProcess

1. Review literature and select appropriate framework.

2. State Research Questions.

3. Design research study using a quantitative, qualitative, or mixed methodology.

4. Select sample.

Research – Stepby StepProcess …Contd.

5. Collect data (data can be qualitative, quantitative,or both).
6. Analyze data (using appropriate techniques).
7. Interpretresults.
8. Disseminatefindings (write and present findings in understandablelanguage).

ResearchProjects

- Research begins with a problem
  - This problem need not be Earth-shaking.
- Identifying this problem can actually be the hardest part of research.
- In general, good research projects should
  - Address an important question.
  - Advance knowledge.

ResearchProject Pitfalls

- The following kinds of projects usually don't make a good research
  - Self-enlightenment.
  - Comparing data sets.
  - Correlating data sets.
  - Problems with yes / no answers.

High-QualityResearch

- Good research requires
  - The scope and limitations of the work to be clearly defined and documented.
  - The process to be clearly explained so that it can be reproduced and verified by other researchers.
  - A thoroughly planned design that is as objective as possible.
  - Highly ethical standards be applied.
  - Data be adequately analyzed and explained.
  - All findings be presented unambiguously and all conclusions be justified by sufficient evidence.

Method,Methodology, and Epistemology

- According to Sandra Harding
  - A research method is a technique for gathering evidence (Means by which data is collected)
  - Methodology is a theory and analysis of how research does or should proceed (Logic applied on data)
  - An epistemology is a theory of knowledge (Essence of analysis)

Choiceof Methods& Methodology

- Depends on
  - Research Questions
  - Research Goals
  - Researcher Beliefs and Values
  - Researcher Skills
  - Time and Funds

WhatI Needto KnowAbout ResearchMethods?

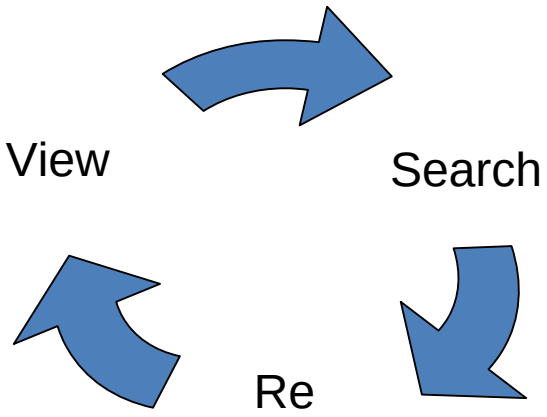
- As a graduatestudent...
  - To be able to read and understand the empirical literature in your field;
  - To become a critical consumer of information.
- As a graduate student preparing for a thesis or dissertation…
  - To be able to both design and implement your thesis or dissertation as well as future studies that interest you.

WhatI Needto KnowAbout ResearchMethods? …Contd.

- As a future practitioner…
  - To be able to intelligently participate in research projects, evaluations, and studies undertaken by your institution.
- As an educatedcitizen ...
  - To understand the difference between scientifically acquired knowledge and other kinds of information.

ResearchIs Cyclic

- Research is an extremely cyclic process.
  - Later stages might necessitate a review of earlier work.
- This isn't a weakness of the process but is part of the built-in error correction machinery.
- Because of the cyclic nature of research, it can be difficult to determine where to start and when to stop.



Step1: AQuestion IsRaised

- A question occurs to or is posed to the researcher for which that researcher has no answer.
  - This doesn't mean that someone else doesn't already have an answer.
- The question needs to be converted to an appropriate problem statement.

Step2: LiteratureReview

- The available literature is reviewed to determine if there is already a solution to the problem.
  - Existing solutions do not always explain new observations.
  - The existing solution might require some revision or even be discarded.
- Be meticulous to check your sources when literature review is done.
- Many trade magazines are not peer reviewed.
  - Professional conferences and journals often have each article reviewed by multiple people before it is even recommended for publication.
  - The IEEE and ACM digital libraries are good places to start looking for legitimate research.

Step3: LiteratureEvaluation

- It's possible that the literature review has yielded a solution to the proposed problem.
  - This means that you haven't really done research.
- On the other hand, if the literature review turns up nothing, then additional research activities are justified.

Step4: AcquireData

- The researcher now begins to gather data relating to the research problem.
  - The means of data acquisition is based on the type of the research problem.
  - This might entail only data gathering, but it could also require the creation of new measurement instruments.

Step5: DataAnalysis

- The data that were gathered in the previous step are analyzed as a first step in ascertaining their meaning.
- As before, the analysis of the data does not constitute research.
  - This is basic number crunching.

Step6: SuggestHypotheses

- The researcher generates intermediate hypotheses to describe a solution to the problem.
  - This is at best a temporary solution since there is as yet no evidence to support either the acceptance or rejection of these hypotheses.

Step7: DataInterpretation

- The researcher interprets the newly analyzed data and suggests a conclusion.
  - This can be difficult.
  - Data analysis that suggests a correlation between two variables can’t automatically be interpreted as suggesting causality between those variables.

Step8: HypothesisSupport

- The data will either support the hypotheses or they won't.
  - This may lead the researcher to cycle back to an earlier step in the process and begin again with a new hypothesis.
  - This is one of the self-correcting mechanisms associated with the scientific method.

Statingthe ResearchProblem

- Once you've identified a research problem
  - State that problem clearly and completely.
  - Determine the feasibility of the research.
- Identify sub problems
  - Completely researchable units.
  - Small in number.
  - Add up to the total problem.
  - Must be clearly tied to the interpretation of the data.

Overviewof Research Methodologies

Descriptive (Qualitative)

- Ethnography
- Case Study
- Survey/Sampling
- Focus Groups
- Discourse/Text Analysis
- Quantitative Description
- Prediction/Classification

Experimental (Quantitative)

- True Experiment
- Quasi-Experiment
- Meta-Analysis

From Lauer and Asher, *Composition Research: Empirical Designs* and MacNealy, *Empirical Research in Writing*

Qualitative - Definition

- A qualitative approach is one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives (i.e. the multiple meanings of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy / participatory perspectives (i.e. political, issue-oriented, collaborative or change oriented) or both. (Creswell, 2003, p.18)

Quantitative - Definition

- A quantitative approach is one in which the investigator primarily uses post-positivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories). (Creswell, 2003, p.19)

Ethnographies

+ Observational field work done in the actual contextbeing studied
+ Focus on how individuals interrelate in their own environment (and the influence of this environment)
- Difficult to interpret/analyze
- Time consuming/expensive
- Can influencesubject behavior

CaseStudies

+ Focus is on individualor small group
+ Able to conduct a comprehensive analysis from a comparisonof cases
+ Allows for identification of variables or phenomenonto be studied
- Time consuming
- Depth rather than breadth
- Not necessarilyrepresentative

SurveyResearch

+ An efficient means of gathering large amountsof data
+ Can be anonymousand inexpensive
- Feedback oftenincomplete
- Wording of instrumentcan bias feedback
- Details often left out

FocusGroups

+ Aid in understanding audience, group, users
+ Small group interaction more than individual response
+ Helps identify and fill gaps in current knowledge perceptions, attitudes, feelings, etc.
- Does not give statistics
- Marketing tools seen as “suspect”
- Analysis subjective

Discourse/TextAnalysis

+ Examines actual discourse produced for a particularpurpose (job, school)
+ Helps in understanding of context, production,audience, and text
+ Schedulefor analysis not demanding
- Labor intensive
- Categories often fluid, making analysis difficult

QuantitativeDescriptive Studies

+ Isolates systematically the most important variables (often from case studies) and to quantify and interrelate them (often via survey or questionnaire)
+ Possible to collect large amountsof data
+ Not as disruptive
+ Biases not as likely
- Data restrictedto informationavailable

Predictionand Classification Studies

Goal is to predict behaviors:

- **Prediction** forecasts an *interval* variable
- **Classification** forecasts a *nominal* variable

\+ Important in industry, education to predict behaviors

\- Need substantial population

\- Restricted range of variables can cause misinterpretation

\- Variables cannot be added together; must be weighted and looked at in context of other variables

PositiveAspects of Descriptive/QualitativeResearch

- Naturalistic; allows for subjects to interact with environment
- Can use statistical analysis
- Seeks to further develop theory (not to influence action); *Prescientific*
- Coding schemes often arise from interplay between data and researcher's knowledge of theory

Problemswith Descriptive/QualitativeResearch

- Impossible to overlay structure
- Impossible to impose control
- Subject pool often limited, not representative
- Seen as more “subjective,” less rigorous
- Beneficial only in terms of initial investigation to form hypothesis

ExperimentalResearch: True Experiment

+ Random sampling, or selection, of subjects (which are also stratified)
+ Introduction of a treatment
+ Use of a control group for comparing subjects who don't receive treatment with those who do
- Adherence to scientific method (seen as positive, too)
- Must have both internal and external validity
- Treatment and control might seem artificial

ExperimentalResearch: Quasi-Experiment(Simulation)

+ Similar to Experiment, except that the subjects are not randomized. Intact groups are often used (for example, students in a classroom).
+ To draw more fully on the power of the experimental method, a pretest may be employed.
+ Employ treatment, control, and scientific method
- Act of control and treatment makes situation artificial
- Small subject pools

Meta-Analysis

+ Takes the results of true and quasi-experiments and identifies interrelationships of conclusions
+ Systematic
+ Replicable
+ Summarizes overall results
- Quality of studies used?

PositiveAspects of ExperimentalResearch

- Tests the validity of generalizations
- Seen as rigorous
- Identifies a cause-and-effect relationship
- Seen as more objective, less subjective
- Can be predictive

Problemswith Experimental Research

- Generalizations need to be qualified according to limitation of research methods employed
- Controlled settings don’t mirror actual conditions; unnatural
- Difficult to isolate a single variable

Testingthe Waters

- How do you come up with a good research question?
- How do you determine if the method you plan to use will answer your question?
- What epistemology should you use to analyze data?

WhatMakes ResearchGood?

- Validity
- Reliability
- Replicability
- Consistent application/analysis
- Trustworthiness
- Rigor

KeyConsiderations toDesign YourResearch Approach

- What question do you want to answer?
- For what purposes is the research being done? i.e., what do you want to be able to do or decide as a result of the research?
- Who are the audiences for the information from the research, e.g., teachers, students, other researchers, members of a disciplinary community, corporate entities, etc.?
- From what sources should the information be collected, e.g., students, teachers, targeted groups, certain documentation, etc.?

KeyConsiderations toDesign Your ResearchApproach … Contd.

- What kinds of information are needed to make the decisions you need to make and/or to enlighten your intended audiences, e.g., do you need information to really understand a process, the students who engage in a process, strengths and weaknesses of a curriculum or program, benefits to students or institution or agency, how aspect of a program are problematic, etc.?

KeyConsiderations toDesign Your ResearchApproach … Contd.

- How can that information be collected in a reasonable fashion, e.g., questionnaires, interviews, examining documentation, observing staff and/or clients in the program, conducting focus groups among staff and/or students, etc?
- How accurate will this information be?
- When is the information needed (so, by when must it be collected)?
- What resources are available to collect the information?
- How will this information be analyzed?

TheImportance ofMethods and Methodology

"The most common error made in reading [and conducting] research is overlooking the methodology, and concentratingon the conclusions. Yet if the methodology isn't sound, the conclusions and subsequent recommendationswon 't be sound."

– Patricia Goubil-Gambrell, additions mine

ResearchAreas inComputer Scienceand Engineering

- Networking
- Architecture
- Algorithms
- Programming Systems
- Database Management System
- Artificial Intelligence / Expert Systems
- Distributed Computing
- Service Oriented Architecture
- Parallel Processing
- Image Processing
- Security

MathematicalTools

- Graph Theory
- Queuing Theory
- Statistical Analysis
- Probability Theory
- Relational Algebra / Relational Calculus
- Markov Model
- Genetic Algorithm

Networking

- Mobile Networks
- Sensor Networks
- Wireless Networks
  - Issues in Routing
    - Reliability
      - Metrics
        - » Signal Strength
        - » Link quality index
        - » Packet Delivery Ratio
    - Security
      - Metrics
        - » Key length
        - » Maximum time taken to break the cipher

Networking …Contd.

- Wireless Networks
  - Issues in Routing
    - Real time
    - Mobility
    - Congestion
  - Mathematical Models in Routing
    - Graph Theory
    - Queuing Theory
    - Genetic Algorithm
    - Probability Theory

Networking …Contd.

- Simulation Tools
  - Wired /Wireless Networks
    - Ns2, Glomosim
  - Mobile Networks
    - Glomosim
  - Sensor Networks
    - Ns2, Glomosim, Jsim, SENSE

Architecture

- Many Core Parallel Architectures and Systems
- Emulation of Highly Parallel Systems (RAMP)
- Self aware Computing Systems
- Low-power System Design
- Reconfigurable Computing
- Architecture for Novel substrates

Architecture …Contd.

- Memory Performance
  - Clock Cycles
  - Bus Timing
- Temporal Locality
- Spatial Locality
- Cache Organization

Architecture …Contd.

- Performance is specific to a particular program/s
  – Total execution time is a consistent summary of performance
- The performance increases are due to:
  – increases in clock rate (without adverse CPI affects)
  – improvements in processor organization that lower CPI
  – compiler enhancements that lower CPI and/or instruction count

Architecture …Contd.

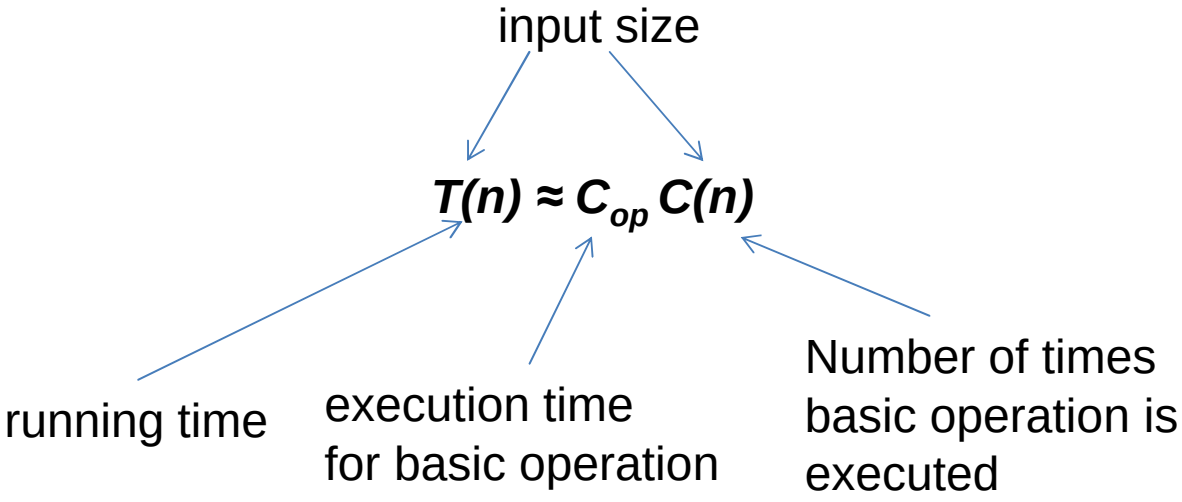
- Architecture Projects
  - RAM page memory hierarchy
    - Should main memory move to what would today be considered the lowest level of cache, and DRAM be treated as a paging device?
  - DRAM as a slow peripheral
    - DRAM, although losing the battle to keep up with the CPU, is not yet a slow peripheral – but shouldn't we plan for the possibility that it might need to be seen that way soon?
  - HRAM algorithm analysis
    - How far can adaptation of algorithm analysis go in adding a memory hierarchy component? There is some work going on in this field called Algorithm Engineering but it's probably more accurate to call "performance tuning" until there is some real science behind making performance predictions. Watch this space for links.

Algorithms

- Issues
  - Correctness
  - Time efficiency
  - Space efficiency
  - Optimality
- Approaches
  - Theoretical analysis
  - Empirical analysis

Theoreticalanalysis oftime efficiency

- Time efficiency is analyzed by determining the number of repetitions of the basic operation as a function of input size
- Basic operation: the operation that contributes most towards the running time of the algorithm.



Empiricalanalysis oftime efficiency

- Select a specific (typical) sample of inputs
- Use physical unit of time (e.g., milliseconds)

OR

- Count actual numberof basic operations
- Analyze the empirical data

Inputsize andbasic operation examples

Problem	***Input size measure***	***Basic operation***
Search for key in list of *n items*	*Number of items in list n*	*Key comparison*
Multiply two matrices of floating point numbers	Dimensions of matrices	Floating point multiplication
Compute a^n	*n*	Floating point multiplication
Graph problem	#vertices and/or edges	Visiting a vertex or Traversing an edge

ProgrammingSystems

- Programming Language Design and Implementation
- Programming Environments and Tools
- Program Analysis and Verification
- Software design, synthesis, and testing

Database

- Research Problems in Data Warehousing
  - Wrapper/ Monitor
    - Translation
    - Change Detection
  - Integrator
  - Warehouse specification
  - Optimizations
    - Update filtering
    - Self maintainability
    - Multiple view optimization

ArtificialIntelligence

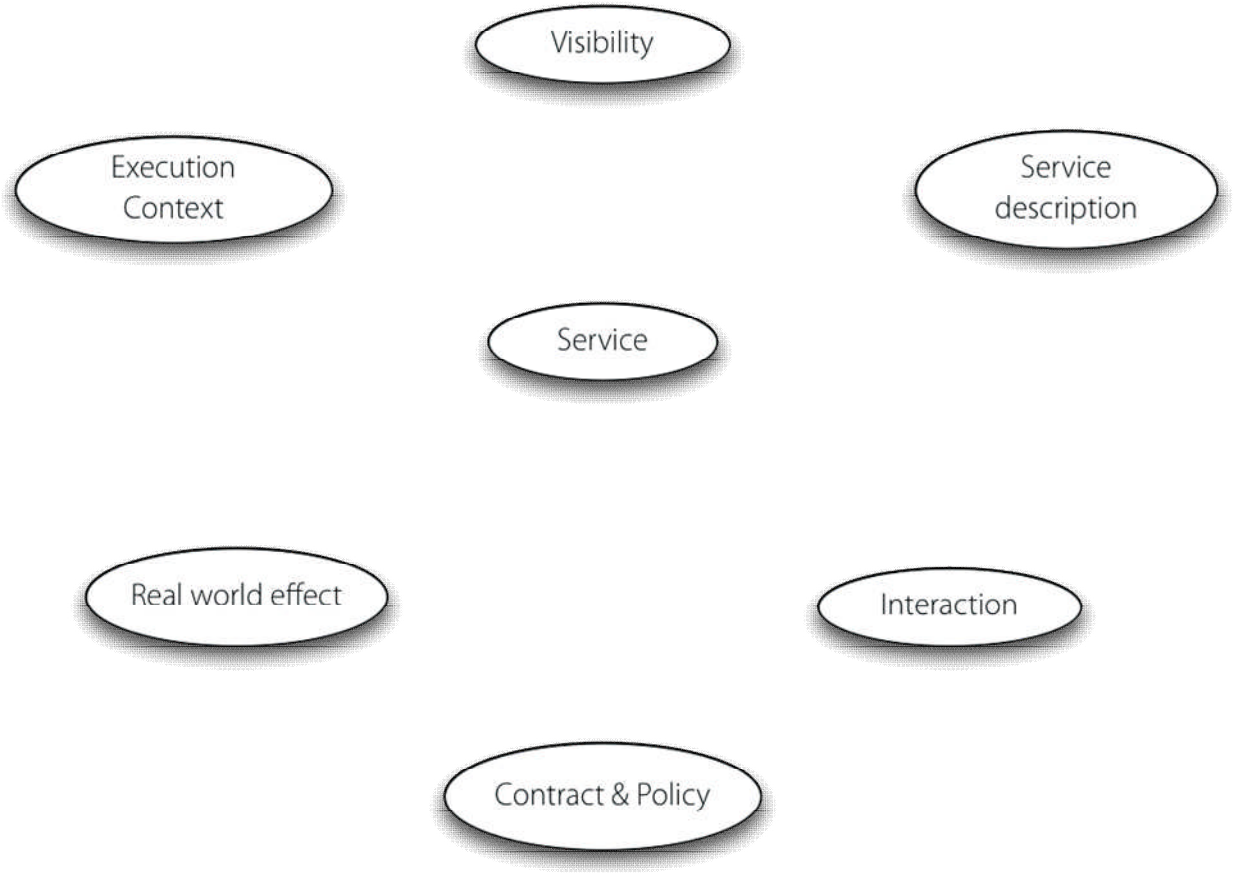
- Learningand ProbabilisticInference
- KnowledgeR epresentationand Reasoning
- Search and InformationRetrieval
- Speech and Language
- Vision
- Robotics

DistributedComputing

- Reliability
- Security
- Scalability
- Redundancy
- Ensuring data integrity
- Synchronizationsupport

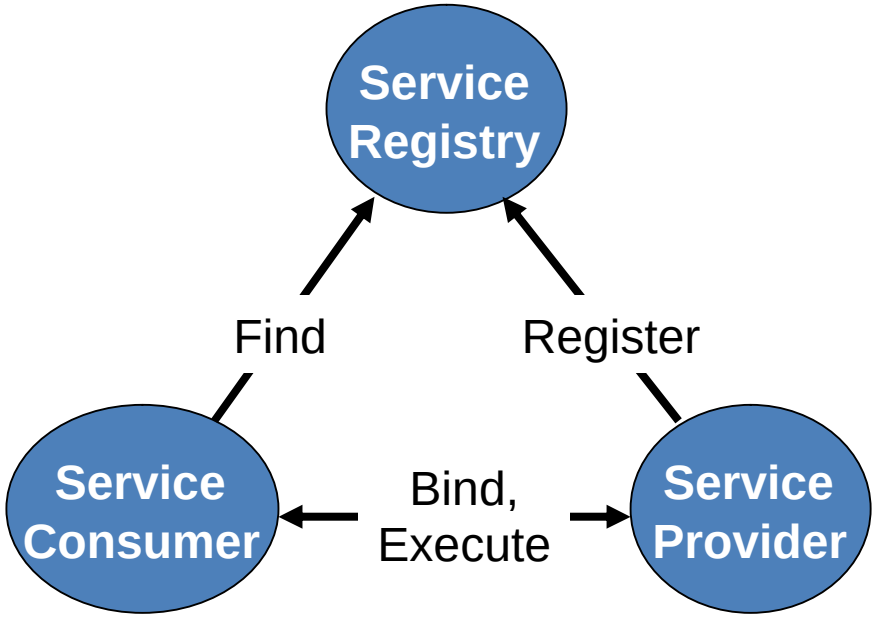
ServiceOriented Architecture

- Achieves LooseCoupling



ServiceOriented Architecture …Contd.

- An SOA application is a composition of services
- A “service” is the atomic unit of an SOA



ParallelProcessing

- Processing of programinstructions by dividing them among multipleprocessors
- Multiprogramming
  - Deadlock
  - Critical Section Routine
- Vector processing
- Multiprocessing

ImageProcessing

- Space DomainImage Processing
- FrequencyDomain Image Processing
- GeometryTransform
- Shape Processing
- Color System
- Noise

Security

- Cryptology
- Trust And Privacy
- Social implications of security
- Sensor web security
- Testbeds for security
- Programminglanguages, and Software Engineering
- Human interfacesand security
- Identityand integrity
- Network security

Summary – 8Steps

1. Originates with a question or problem.
2. Requires clear articulation of a goal.
3. Follows a specific plan or procedure.
4. Often divides main problem into subproblems.
5. Guided by specific problem, question, or hypothesis.
6. Accepts certain critical assumptions.
7. Requires collection and interpretation of data.
8. Cyclical (helical) in nature.

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Thankyou

Go forthand research….

….but be careful out there.