Research Manual of SERG

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Preface

Over the years I have seen many undergraduate and graduate students who are interested in doing research unprepared at the beginning of their journey. In the past, a graduate-level course *"Research Methods"* was usually offered to prepare undergraduate and graduate students for various needs, ranging from term projects to degree-bearing theses. Unfortunately, with the overwhelming growth of information in digital technology and its subsequent impact to our Bachelor's and Master's curricula in the College/School of Engineering, only few students can find themselves fortunate enough to the offering of such courses. Many students learn how to do research in unorthodox approaches, and most of them learn by trial-and-error. As a result, both faculty and students are frustrated, and large amounts of effort and time are inefficiently spent.

This Member's Manual is not a replacement for the needed course *"Research Methods"*, neither is it a replacement for many available research methodology titles in the market. It is merely a first attempt to prepare the graduate students in my research group in the Department of Civil and Environmental Engineering at UMass Lowell to conduct their research with the necessary knowledge toward a proper ending. Students should use this Manual to realize and identify the shortcomings in their research philosophy, approach, and skills in order to improve themselves, and eventually, to achieve excellence in research. As a result, this Manual only contains my perspectives on research.

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I. Research Philosophy

A researcher is an individual who has a clearly defined, specific research question to pursue its answer, using theoretical derivation, numerical simulation, and experimental investigation.

Conducting research is not for pursuing an **academic degree** but an endeavor demonstrated by intellectual individuals to challenge themselves to integrate and master their learnt knowledge. Academic degrees are merely a byproduct to completed research work.

Research problems are typically originated from the following sources: **imagination** and **curiosity**. Even when you are solving a research problem given by your advisor, he/she was the curious one with imagination who proposed the problem. While conducting research of this nature, it is your opportunity to discover new problems from the research.

Doing research is not and should not for **money**. A good research topic aims at solving scientifically valuable problems, not financially rewarding problems. Nonetheless, financial compensations are always provided to those doing research for living. However, messing up the order of priorities can lead to a regrettable life, usually a mistake in life too late to rectify.

Conducting research is not a nine-to-five job, although the professions related to research are still well-defined when it comes to **working time**. A researcher's job is done when the research problem is solved, not when one has spent nine hours in front of a computer or a desk.

Doing research is not solving homework problems. For homework problems, there are already **answers** to them. For research problems, there should be only **hypotheses** to them.

It takes years for one to become an expert in any field, therefore, patience is considered a virtue. However, one cannot forget the fact that, research is also a global competition. Whoever first solves a given research problem will put all other competitors out of the game. There is no place for second placers in the history of science.

II. Research Approach

When conducting your research, four stages (at least) are expected in this process to assure the quality of your research.

1. **Problem definition** – Researchers are driven by the desire to solve research problems. Without a problem defined beforehand, there is no research to be solved/done. Many times people tend to solve multiple problems at once (or in one research project). In any case, problems must be specific and tangible within expected time to complete the work. For those who are experienced enough to identify tangible problems from holy-grail-type problems (e.g., the meaning of life), considerations must be given upon the available resources in individual researchers' environment, such as faculty advisors, computer software, laboratory equipment, and the level of financial support. One cannot propose to investigate a research topic without estimating the likelihood of success by reviewing the resources he/she has access to.

2. **Literature review** – One must review what have been done in order to verify the **originality** of the proposed research problem at the beginning of research. There is no shortcuts in this stage. Bypassing this stage can result in catastrophic consequences such as forfeiting all research effort and result one has invested for years. The quality of literature review preserves the originality of research.

3. **Original work** – One must conduct original work via the following approaches:

   - **Analytical derivation** – One way to solve research problems is by mathematical or analytical derivation. This is achieved by the following steps:
     (a) **Formulation** – Develop the governing equation of the given problem. Most engineering problems are governed by physical laws which are ordinary or partial differential equations. In the fields of acoustic and electromagnetic scattering, integral equations are usually encountered.
     (b) **Analysis** – Solve the analytical solution to the governing equation. For the governing equations whose analytical solutions may not exist, approximate or bound solutions are

used instead. This can be achieved by limit analysis or perturbation analysis.

- **Numerical simulation** – The power of computing is no doubt the driving force for the advances in science and technology today. Numerical simulation using digital computers has been proven to be a legitimate approach in obtaining solutions to research problems in many disciplines. Students may find themselves lost in the rapid development of computer languages and the swift updating of commercial software packages. Currently, the most acceptable scientific computing tool is **Matlab** (short for **Mat**rix **Lab**oratory) by MathWork, Inc. In civil engineering or engineering mechanics, familiarity with **C++** and **Fortran** (short for **For**mula **tran**slator) is always a plus to those in need of writing his/her code (or revising others' codes).

- **Experimental investigation** – In civil engineering and many other engineering disciplines, experimental result stands for the final verdict. While running experiments sounds exciting and usually leads to valuable data for theoretical development, one cannot ignore the challenges in experimental work, including experimental capability in laboratory, human and machine errors in experiments, measurement errors, background noises, and validation of experimental data.

4. **Summary and conclusion** – During the research, carefully document everything as complete as possible. Derivation notes, simulation notes, experiment notes, raw data files, and even hand sketches may turn out to be indispensable in this final stage of research. One should always bear in mind that, the outcome or product of research is **new knowledge**. **If there is no knowledge to be reported at the end of research, no research has actually been done.**

III. Research Skills

There are few necessary skills for a researcher to equip himself/herself such that once call it a proper ending to any research problems. The following abilities are identified for those who are about to start their research activities.

1. **Ability to write scientifically** – Writing skill is the most fundamental skill, and yet, remains the most difficult one to develop. Many researchers know how to do research but don't know how to write. Although professional language service providers are available, there is no one better than the author to document and report his/her own research work. The criteria for scientific writing are:

   (a) **Clarity** – Write clearly. Avoid long and complicated sentences, especially for inexperienced, foreign researchers whose mother tongue is not English.

   (b) **Consistency** – Write consistently when describing a scientific phenomenon. For beginners, remember the rule: *"A is A, and B is B"*. If you change the name of an object you mentioned in your writing, you meant different objects at that point.

   (c) **Logic** – Clarity and consistency cannot be achieved if there is no logic in the writing. Logic is best described by the cause and effect relationship. Reversing the order will only lead to confusing explanations.

   If you cannot write, you cannot publish. If you cannot publish, you cannot secure your credits (and cannot graduate if you are doing degree-bearing research).
   A document on *Guidelines on How to Write Technical Reports*, prepared by the College of Engineering, Writing Improvement Workshop in 1999, is attached in Appendix A for the reference of readers.

2. **Ability to survey existing literature** – In this digital era, most of the information can be found at your fingertips. Even though, one needs to know how to ask right questions using right keywords to find the information he/she needs. This ability is crucial to the quality of literature review in every research problem. Simply the following:

- If you cannot survey existing literature for the research problem you are bound to start, you don't know what have been solved/done.

- If you don't know what have been solved/done, you don't know what is new. If you don't know what is new, your work is not original.

- If your work is not original, then you are not doing research.

3. **Ability to perform research** – There are basically three approaches to do research; analytical, numerical, and experimental. As a Master's student, you need to master at least one approach. If you are a Doctoral student, you need to master them all.

4. **Ability to summarize research findings/discoveries** – After going through all the troubles and overcoming all difficulties in your research, you are about to summarize your findings. The best starting point is back to the origin; your hypothesis to the research problem. Did you prove or disprove your hypothesis at the end, from your result? Additionally, did you find something unexpected and new? What can you teach others from your research work?

5. **Ability to present result** – Besides publication, modern researchers ought to know how to orally explain their research work by delivering seminar and conference talks on their research. There are literally gigantic amounts of titles on how to deliver a successful/effective presentation/talk in the market. Those in engineering and science who are interested can simply look into the resources in business.

To develop all these abilities in time, one usually needs an advisor to provide guidance. Nonetheless, rank is not always the only criterion in finding advisors. One can and should learn from those who are good at certain aspects, even he/she is either in your class or junior than you.

Epilogue

As stated in the Preface of this Manual, this Manual is a first attempt to providing an up-to-date, introductory overview to those who want to do research in my group (for whatever reason). You need to discuss with your advisor as frequent as possible, and yet, you need to think about possible answers before you meet your advisor. You are encouraged to share your questions with other group members, but you must have sound reasons for taking answers from other people.

While one can learn more from mistakes than successes, it is important not to be used to repeatedly making same mistakes.

Be open-minded.

Appendix

- Guidelines on How to Write Technical Reports, College of Engineering, UMass Lowell (1999)

- Tips for Talks – Help for Giving a Talk or Lab Meeting, Biology UROP and Mentoring Program, MIT (2014)