What are the Differences between Solving a **Homework** Problem and Solving a **Research** Problem?

Minh N. Do

Electrical and Computer Engineering

University of Illinois at Urbana-Champaign

"Most advances are made in response to a need, so that it is necessary to have some sort of practical goal in mind while the basic research is being done; otherwise it may be of little value."

John Bardeen (two Nobel Prizes in Physics)

Introduction

- Transition from an undergraduate student to a graduate student
  - How to become an **independent researcher**?

- Before graduate school:
  - Mostly trained to solve homework problems

- In graduate school (and beyond, for researchers):
  - Ability to solve research problems is the key for success

- Analogy: winning a battle and winning a war!

Solving a Homework Problem

- **Example**: Show that $\{\operatorname{sinc}(t-n)\}_n$ is an orthogonal basis for bandlimited functions $\operatorname{BL}([-\pi, \pi])$

- **Required skills for solving homework problems**:
  - Knowledge
  - Creativity
  - Persistence

- **Typical:** Problem $\rightarrow$ Solution
  - Problem is well defined
  - Know that a solution exists!

Solving a Research Problem

- **Example**: Can we recover a function from its samples?

- Research problems are typical fuzzy and open ended
  - Problems are **not** clear and well-defined
  - Problems are **not** even exist before

- **Key**: being able to ask the right questions and refine them

- We need not just to solve the problem but also convince the world that we actually solve it!
  - Perform experiments to confirm the theory
  - Demonstrate the impacts in real applications and technology

"There are many things one doesn't understand and therefore, we ask them why don't you just go ahead and take action, try to do something? You realize how little you know and you face your own failures and you simply can correct those failures and redo it again and at the second trial you realize another mistake or another thing you didn't like so you can redo it once again. So by constant improvement, or should I say, the improvement based upon action, one can rise to a higher level of practice and knowledge."

Fujio Cho (President of Toyota)

Five Steps in Solving a Research Problem

- **Step 1:** Define the problem (scope, area,…)
  - Review literature (lot of reading, but not too much)
- **Step 2:** Formulate the problem (into a homework problem)
  - Find the right model, setup
  - Introduce assumptions to simplify the problem
- **Step 3:** Solve the problem (~ solve a homework problem)
  - Many times need to validate with experiments, applications
- **Step 4:** Interpret the solution
  - Go back to the original problem: new insights, new methods,…
- **Step 5:** Disseminate the results
  - Papers, presentations, patents,…

Define/Formulate a Research Problem

- **Fact**: Most of engineering problems are ill-posed!

- Often we need to redefine/reformulate the problem to make it solvable
  - Imposing realistic assumptions
  - Add constraints
  - Simplify the problem or model

- **Engineers**: We are allowed to change the problem!

- Many times, being able to define/formulate a research problem is half of the work!

Some Techniques in Formulating Problems

- Keep simplifying the problem until it is solvable (e.g. to a special case) and then try to generalize/extend the solution
  - Simple problem often gives clear insight and intuition
  - If we cannot solve a simple version of the problem then we also cannot solve the complex version
- Multiresolution technique: start with a coarse and solvable problem and successively extend it to make it more realistic
- Look at the data!
- Ask the converse questions
  - **Example**: we know that **bandlimitedness** leads to **samplable**; but what are **other samplable signals**?

Required Skills for Solving Research Prob

- Knowledge (much wider)
- Creativity
- Persistence (much more)
  - If we keep trying hard, something good will come out

- **Ask good questions**
- Faith (this problem can be solved!)
- Flexibility (if not, how can I reformulate it to be solvable!)
- Communication skills for disseminating results
- See the the big picture
- Organized, motivated, and have a sense of purpose

Epilog

- Actually, research are typical much more unstructured than what I just described

- But a good research should solve a good and relevant problem

- Further reading:
  - "*How to solve it*" by G. Polya, Princeton University Press

"Your work is going to fill a large part of your life, and the only way to be truly satisfied is to do what you believe is great work. And the only way to do great work is to love what you do. If you haven't found it yet, keep looking. Don't settle."

Steve Jobs (CEO of Apple Computer)