AN APPROACH TO RESEARCH IN ROBOTICS

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QUESTIONS AT YEAR 20

- Objective of cutting-edge research:
  - Change the way the world thinks. Use theory, analysis and demonstration.
  - At Carnegie Mellon, we expect students to be world's expert by they time they complete PhD
- Getting started seems mysterious:
  - New material
  - Standards are not obvious
  - Have to pick topics of the right granularity to get results

IS THERE A HOPE?

- Topics, research styles, resources vary a lot
- Is it possible to finding commonalities, of generalizing on how to do research?

OBSERVATION (1)

- *The artifacts of science are not the same as the process of science*
- Artifacts:
  - A, B, C = > D
- Methods:
  - C, A, =?D, reformulate A, C, B, change D
- Implication: blundering around is part of the process

OBSERVATION (2)

- *Robotics in a constructive, integrative discipline*
- Generally we try to address "how to" rather than "what" & "why" (domain of natural sciences)
- Impact is greatest when one is either
  - the FIRST to show a new concept or application in new domain
  - or, have SIGNIFICANTLY better results than the state of the art

OBSERVATION (3)

Natural progression of ideas:

- *Feasibility*: can it be done at all?
- *Robustness*: can it be done insitu?
- *Efficiency*: how to make the process viable?
- *Scalability*: how to scale to many?

A PROCESS

- I implied that I didn't have a formula (I lied).
- I propose a 5-step process. Best use is to get people to think about processes, not as a template.
- The process is rarely linear. Think of it more like a story line-- all parts are being developed continually.

STEP 1: COME UP WITH A WELL ARTICULATED PROBLEM

- "Well articulated"
  - can be used in an elevator speech.
- "Problem"
  - think of problem from the perspective of someone who wants a solution but doesn't care about the form
  - problem can't contain a solution

STEP 1: WHERE DO PROBLEMS COME FROM?

- Origins:
  - Your advisor/boss tells you to solve it
  - A sponsor wants a problem solved
  - Start with ideas that play like a song you can't get out of your mind
- Your job is to define the problem such that the statement alone makes it seems worthy of consideration
- How to start: think of a capability in the world that you would like to produce that doesn't exist today.

STEP 1: SOVING PROBLEMS VS. PRODUCING SOLUTIONS

- Bumper sticker seen: Artificial Intelligence: A technology in search of a problem
- Personal Style: start with a problem so you will know if you have solved the problem.
- Problem solving doesn't mean a point solution or very applied research
- Inventing generalized solutions (particle filtering, market based systems, architectures, POMDP solvers) is tricky. Great potential but hard
- Even if the intention is to propose a body of solutions, motivate with problems,

STEP 2: SHOW THAT SIMPLE-MINDED SOLUTIONS DON'T WORK

- "Simple-minded solutions"
  - Top 1-2 ideas that reasonably intelligent people would think of in one day. Implementable in no more than one week.
  - better if the solutions are not exhaustive
- This provides a benchmark on what can be done easily.
- Many elegant solutions never do significantly better
- Will help identify the tough parts

STEP 3: SHOW THAT THE FULL BLOWN FORMULATION IS INTRACTABLE

- Think of the problem in terms of canonical approaches. Examples:
  - Graph search
  - Markov Decision Processes
  - Constraint optimization
  - Direct/Indirect adaptive control
- Will help when things don’t work & help with metrics
- Argue with complexity measures AND compute time

STEP 4: THE TWIST

- Find way of thinking about problem that gives you the performance of the full blown solution with the cost of the simple solution.
- Often done with a “good approximation” or a “better representation”. Examples:
  - learning a cost function online
  - dimensionality reduction
  - solving a dual problem
  - breaking up a problem into parts that are easier
- Good solutions come in classes that can work with many variations of the problem

STEP 5: A COMPELLING DEMONSTRATION

- Significance should be understandable to someone who doesn't understand the method.
- Show variations of the problem.
    - different assumptions
    - effect of scale
- Magic Numbers: 3, 10, 100, 10,000
- Simulation OK for showing variations, not for making the main point.

A FEW NOTES

- Leave the unified theories for the dinner speeches. Concentrate on a bite sized problem.
- Analyzing performance is essential.
- Comparison to other methods is important
- Clarifying limitations is as important as showing successes.
- When successful, craft clear statement on KEY INSIGHT that makes the difference. This is the take home message.

WHERE IS THIS APPLICABLE??

- Better for “useful” as opposed to “elegant” research
  - Better for engineering than mathematics
  - Doesn’t work for the natural sciences.
  - Addresses “how to” rather than “ what” & “why”
- Ideally spans conference papers to doctoral theses

FIVE STEPS

1. Come up with a well articulated problem
2. Show that simple solutions are not sufficient
3. Show that full-blown formulation is intractable
4. Create a Twist
5. Produce a compelling demonstration