AN APPROACH TO RESEARCH IN ROBOTICS

Sanjiv Singh
Robotics Institute
Carnegie Mellon University

Nov 9, 2010
QUESTION 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
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?
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: SOLVING 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