Learning to Learn
The Art of Doing Science and Engineering

Session 1: Orientation

Purpose of the course
Prepare you for your technical future
Much technical content is covered
  • but that material is review, not the point of the course
Style of thinking is the center of the course
  • examine, criticize and display styles of thinking
  • complement existing courses, what you need to know
Concerned with educating, not training you

Dilemma
Some things aren’t expressed well in words
  • Early Greeks (Socrates, Plato) believed anything can be described in words
  • Principles of scientific reductionism
Contrast: need for experience
  • Gods, truth, justice, arts, beauty, love
Style of thinking is a topic in its own right

First person
Must present first-hand knowledge and experience to be effective in this course
  • breaks scientific taboo, analysis is usually impersonal
  • nevertheless the most effective form for this course
  • goal is to change listeners’ minds, ways of thinking
Unfortunately can sound like “bragging”
  • “Hamming on Hamming”
  • apologies for that

Coaching
Role is that of “coach”
  • students must still do the work themselves, mull things over, compare to own experiences, discuss
  • make some points part of your way of doing things
Style: comparison to painting
  • fundamentals, apprenticeship, mastery, forge style out of combined influences and native ability

Education versus training
Education is what, when, why to do things
Training is how to do it
Either one without other is not of much use
Focus on future

Examine likely state of Science
- at time of your greatest contributions, say year 2020

Since Newton’s time, scientific/engineering knowledge has doubled every 17 years
- various metrics, e.g., publication count, size of libraries
- number of people employed in technical jobs
- growth rate of scientists: currently almost 90% of all scientists who ever lived are now alive!

Exponential change for amount of human knowledge

1. Assume knowledge doubles every 17 years
   - Equation for first assumption becomes
   $$y(t) = a \cdot e^{kt}$$
   $$\frac{y(t)}{y(0)} = \left(\frac{a}{b}\right)^{17/17} = e^{17k}$$
   $$b = -\ln\left(\frac{y(t)}{y(0)}\right) = -0.04077$$
   $$\frac{y(t)}{y(0)} = e^{17k}$$

2. 90% of scientists who ever lived are now alive

Example comparison of two assumptions

Goal: verify your thoughts quantitatively
- it is very significant to consider that aggregate sum of all human knowledge increases exponentially
- how can we test such ideas?

Knowledge increase over time

<table>
<thead>
<tr>
<th>X years</th>
<th>17</th>
<th>27</th>
<th>34</th>
<th>39</th>
<th>44</th>
<th>48</th>
<th>51</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y factor increase</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

“Back of the envelope” calculations are important

Back of envelope computations thus show that assumptions are reasonably compatible
- Also note that these relationships hold for all time, if assumptions remain valid
Knowledge obsolescence over time

15-year half life
- in 15 years, half of what you have learned will be technically obsolete
- success in your chosen area may make your scientific and engineering knowledge irrelevant
- Hamming example: transistors, vacuum tubes

Dealing with technological change

How to cope?
- concentrate on fundamentals
- develop ability to learn new fields of knowledge

What is fundamental?
- topic has lasted a long time
- fundamentals can be used to derive remainder of field

Science versus engineering

Glib descriptions:
- In science, if you know what you are doing, you should not be doing it
- In engineering, if you do not know what you are doing, you should not be doing it

In actuality:
all engineering involves creativity, and all science involves some practical engineering

Role of history

Often used as long-term guide
- some believe it repeats, others believe the opposite!

Best predictions are based on understanding fundamental forces involved
- Often it is not physical limitations controlling progress
- Human-made laws, habits, organizational rules, regulations, personal egos, inertia can dominate

History is bunk? (Henry Ford)

History is seldom reported accurately
- no two reports of what happened at Los Alamos during WWII seem to agree
- pace of progress seems to disconnect the technological future from the past

Apparent contradictions in historical works
- past determined by big trends, bigger than individuals
- future has great possibilities for individual change

Handling contradictions of a historical perspective

Can cope at least four ways:
1. You can simply ignore it.
2. You can admit the contraction.
3. Decide that past was less deterministic, with individuals able to make large contributions.
4. Decide that future is less open ended than desired, with less choice than there appears to be.
Drunken sailor progress

Well-known relationship
- random walk from starting point traverses average distance proportional to square root of n steps
- random walk towards a pretty girl traverses average distance proportional to n steps (much! farther)
- Moral: having a goal makes a big difference

Thus having a vision of your future is critical
- Accuracy of having the precisely correct goal at every step along the way is definitely secondary

Computers will dominate your technical future

Many advantages over humans
- Economics: far cheaper, getting more so
- Speed: far, far faster
- Accuracy: far more accurate (precise)
- Reliability: far ahead (often built-in error correction)
- Rapidity of control: makes modern aircraft feasible
- Freedom from boredom: overwhelming advantage
- Ease of training, hostile environments, personnel...

Developing vision of future

Devoted 10% of time (Friday afternoons) to trying to understand future of computing

Three key questions (corresponding fields)
- What is feasible? (Science)
- What is likely to happen? (Engineering)
- What is desirable to happen? (Ethics, morals, values)

Also a religious course

With apparently one life to live on this earth, you ought to try to make significant contributions to humanity rather than just getting along through life comfortably.

Choice of goals is yours, but absence is mere existence. Socrates (469-399 BC) said
- “The unexamined life is not worth living.”