Research quests

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Part I
General thoughts

For charactarization of important themes, modes and efforts of various types of research, see the relevant reference sheets. Potential thesis topics:

Part II
Computer science

1 Theoretical computer science

Problems dealt with in theoretical computer science ultimately have their origin in practical problems. But, some of these problems are so hard that many subsidiary theoretical questions arise. Eg: Computational complexity research.

Our descendents, equipped with genetically engineered brains and better interface with machines, may be much better equipped to do deep theory. Perhaps theory is better served by accelerating their arrival.

2 Experimental computer science

Often, researchers in such areas use experiments when it is difficult to theoretically prove a conjecture. Eg: The study of wireless and wired networks, distributed systems, computational biology. The ideas are mathematically well motivated but unproved. Eg: Dimensionality reduction using Principal component analysis.

A rich source of problems is found in the act of building systems. Characterization of research effort

3 Algorithms

Advantage of being an algorithmicist: can play in everyone's backyard.

Natural algorithms: Algorithmic models of biological systems.

4 Numerical analysis

Enter the field of continuous mathematics algorithms from the perspective of theoretical CS.

5 Graphs

Analytically prove power law group size distribution in KDD affiliation networks paper.

5.1 Graph generation with certain community structure

Given the k*k q(xhat, yhat) matrix, which specifies the edge densities between various node clusters, make a generative model which produces graphs with that clustering structure, such that it possesses various static and temporal properties of real world graphs.

- A trivial solution seems to exist if the diagonal entries heavily dominate others. Is this well motivated?

  This was implemented in R using igraph. Power law degree distribution was experimentally verified. Yet to be verified: cluster structure.

  Analytical proof of cluster structure pending. Is this an (a, b) cluster in the Tarjan sense?

- Verify the matrix generated by the implemented code by applying information theoretic coclustering. Obstruction: inability to write sparse matreces due to lack of necessary library in old R version.

5.2 Graph generation with hierarchical community structure

Construct a graph generative model which, besides having good static and temporal properties displayed by graphs evolved using other models, also shows hierarchical community structure.

- This can be done if the idea to use affiliation networks algorithm to generate clusters and then interconnect them works.

6 AI

Expert systems which write text books and papers to report findings to other machines and men.

Agents which learn from each other.

Vision is the current bottleneck in robotics. Bad vision ability is stopping massive robotic deployment in the world.

7 Pattern recognition

Understand where Naive bayes regressor works better than other regression algorithms.

7.1 Learning theory

Consider the problem of learning a decision tree with a 1/n correlated parity, given a noisy parity learner which only works with constant noise.

Theoretical characterization of the protein structure prediction algorithms: How accurate can a certain algorithm be?

8 Human machine interface

Thought to speech system.

Part III
Biology

What is the mechanism of generation of antibodies?

9 Biostatistics

The actual expected amount of DNA and genes shared by siblings.

10 Biomedical engineering

Sequence human genome within 10 minutes

11 Neuroscience

Neuroscience of primitive animals

12 Structural biology

Protein structure prediction as a Constraint satisfaction problem: o In iterative formulation: + backtracking search o In complete formulation: + Minimum conflict heuristic

Use the fact that a significant part of the protein is disordered, with the "fail first" heuristic to undertake more efficient conformation space search.

Ensuring proper sampling of the conformation space: o Start from the structure of a denatured protein. o Cotranslational folding: Fold a protein as it folds.

predict changes in shape from point mutations : use this to predict structure!

Explore the use heirarchial task network planning in finding protein structure.

Consider the peptides as robots in a swarm. Use this to predict structure.

the problem of deciding whether a molecule in one conformation can spontaneously go to another conformation.

Structural genomics: what is the optimal set of proteins to me modelled?

MBS in protein-ligand docking.

What heuristics may be used in protein structure prediction?

Map the structure of the conformation space.

Part IV
Mathematics

13 Recreational maths

Minimum information required for deterministic sudoku gameplay.

Part V
Physics

14 Mechanics

Derive the principle of conservation of momentum (and energy) for a system with non conservative forces such as friction by showing that the momentum lost by the sliding body is converted to heat in the perturbed molecules where friction occurs.

A molecular mechanics explanation for elasticity?

A statistical mechanics explanation for the omni-directional nature of a liquid's pressure, though it is influenced by gravity.