Spring 2011 LTI Colloquium Report

CCG, Fractal, and Emergence

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This is a response to the talk by Mark Steedman on "The Statistical Problem of Language Acquisition". In this talk, Mark reports on recent work with Tom Kwiatkowski, Sharon Goldwater, and Luke Zettlemoyer on semantic parser induction by machine from a number of corpora pairing sentences with logical forms including a corpus consisting of real child-directed utterance from the CHILDES corpus. The talk shows that this class of problem can be solved if the child or machine initially parses with the entire space of possibilities that universal grammar allows under the assumptions of the Combinatory Categorial theory of grammar (CCG), and learns a generative statistical parsing model for that space using EM algorithm-related methods such as Variational Bayes learning.

An interesting question comes into my mind during this talk is that although CCG is a good model of how human process language, can we deduce CCG from a more general form of intelligent process?

"I once asked Bravura whether there were any Kestrels in his forest. He seemed somewhat upset by the question, and replied in a strained voice: 'No! Kestrels are not allowed in this forest!" –Raymond Smullyan, *To Mock a Mockingbird*

In Mark Steedman's book "The Syntactic Process" he raised questions like "why should natural grammars involve combinatory rules?" "why are the combinatory apparently confined to composition, type-raising, and substitution?" "why are the syntactic combinatory rules further constrained by the Principles of Consistency and Inheritance?". In my opinion, these characteristics of CCG reflect the nature of the problem of communication with natural language: i.e. generating sequences of words from semantics, and parsing sequences of words into semantics. It is certainly an important

and interesting to study this nature of language, but a more important and interesting problem is the general intelligent mechanism that can perceive this nature and come up with structures and processes that correspond to it. The later problem is more important, because it is the key to a wider range of intelligent behavior like vision, planning, and control.

An important image I'd like the reader to have in mind is a famous fractal image called the Mandelbrot set. The Mandelbrot set has become popular outside mathematics both for its aesthetic appeal and as an example of a complex structure arising from the application of simple rules, and is one of the best-known examples of mathematical visualization. The Mandelbrot set shows distinct structures with infinite details. However, the mechanism that generates these structures is strikingly simple. Technically, the Mandelbrot set is the set of values of *c* in the complex plane for which the orbit of 0 under iteration of the complex quadratic polynomial $z_{n+1} = z_n^2 + c$ remains bounded. That is, a complex number, *c*, is part of the Mandelbrot set if, when starting with $z_0 = 0$ and applying the iteration repeatedly, the absolute value of z_n never exceeds a certain number (that number depends on *c*) however large *n* gets. On one hand, we can see that the mathematical formula that generates the Mandelbrot set consists of less than ten characters. On the other hand the generated patterns seem to present infinitely large amount of information, which cannot possibly be encoded in a few characters. An intuitive explanation to this contradiction, is that this information comes from the nature of complex numbers, and the formula is just a mechanism to perceive and expression this information.

Similar analogy can be drawn to human intelligence. People all agree that their brains are very complex, having countless mechanisms corresponding to different tasks like language, vision, planning, and control. However, their brains are not born with such full complexity. Many structures are acquired to reflect the nature of communication problem, the laws of physics, and human society. The actual mechanism that made it possible for the brains to perceive and create structure is very likely to be much

simpler than its created structures: e.g. a ccg parser, or an object recognition system. Studying certain types of intelligence behavior can help us mimic certain type of intelligent behavior, and create useful systems. However, it can be much more fruitful to seek out a fundamental mechanism, which can generate these different behaviors through interactions with the nature. The strongest type of intelligence is not the ones people create, but the ones that emerge from the nature itself.

Corollary: it does not take a complex man to make great creations. By being a humble messenger of the nature, a mere mortal man can create eternal beauty. All it takes is to perceive the nature, and put it down in certain form.