Computing meaning: an application of natural language processing in grid puzzles

**Problem Statement:**

Inferring semantic information is a notoriously difficult task in natural language processing. Current statistical parsers produce syntactic parses which are locally coherent but may exhibit significant global semantic problems. In this proposed investigation, we will attempt to extract semantic information from English text by constraining the possible meanings to a grid puzzle scenario. The puzzle framework will enable us to focus on key words in the puzzle instructions and attempt to extract their meanings based on the assumed context. Further work can incorporate the puzzle constraints uncovered by the current project from the instructions into a constraint satisfaction problem which is used to solve the corresponding puzzle.

**Specification:**

In order to completely define this project, we need to consider what kinds of puzzles, instructions, and natural language processing it will involve.

**Puzzles:**

Puzzles must be solvable and be presented on a finite grid. Examples of three popular grid puzzles are given in Figure 1.
Instructions:

Instructions must be written in paragraph form in English and must pertain to a grid puzzle. An example instruction for a KenKen puzzle reads:

Fill in each square of a cage with a number. The numbers in a cage must combine—in any order, using only that cage’s math operation—to form that cage’s target number. You may not repeat a number in any row or column. You can repeat a number within a cage, as long as those repeated numbers are not in the same row or column.

Syntactic Parsing:

The instructions will be parsed by an existing parser. A likely candidate is the Stanford statistical parser which is able to parse many difficult structures but has significant trouble with imperative sentences.

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1 Source: http://i.i.cbsi.com/cnwk.1d/i/bto/20090109/kenken_8x8_CNET_hard_1.9.2009.png
2 Source: http://www.logicgamesonline.com/images/sudoku-puzzle-256.png
3 Source: http://img.geocaching.com/cache/f0bdf89a-b00e-414e-be0b-aaaaf3ae836d6.jpg
4 Source: http://www.kenken.com/howto/solve
frequently found in puzzle instructions. The most likely parsing tree produced by the Stanford parser of the first sentence of the KenKen instructions is as follows:

```
(Root
  (S
    (VP (VB Fill)
      (PP (IN in)
        (NP
          (NP (DT each) (NN square))
        )
      )
    )
  )
)
```

We can see that the parser has committed a few semantic errors, such as neglecting to recognize that “of a cage” is a whole prepositional phrase and that it relates to “each square” instead of “with a number”.

**Possible Approach:**

The starting points for our algorithm will be parses of the instruction sentences provided by a statistical
parser. We plan to accept these parse trees as locally valid. We will then need a way to aggregate the necessary vocabulary to extract the semantics and create a target domain for the corresponding constraint satisfaction problem. The next step may be to explore moving these local parses to different nodes in the tree in a way that results in a semantically and syntactically valid sentence. We may introduce a penalty for moving parts of the original parse tree and a reward for improved semantic coherence. The algorithm will avoid the combinatorial explosion in possible number of new parses by considering that the sentences must describe a solvable grid puzzle.

**Deliverables:**

By the end of this term, we plan to have an algorithm which constructs a more semantically valid parse of a grid puzzle instruction than the tree produced by the Stanford statistical parser. The implementation of this algorithm will output the meaning of each word in the instruction in the context of the sentence. There will also be a corresponding report of length no less than 10 pages detailing the algorithm and its performance.