

# Assignment 3

CS 581

Due October 25, 2018

**Problem 1 [10 point]** Define a two-dimensional Turing machine *2DTM* as a Turing Machine with a 2-dimensional tape. When the head is scanning a symbol it can move left, right, up, or down. Prove the equivalence between *2DTM* and a single-tape *TM*.

**Problem 2 [10 point]** Let a *Queue Automaton* be defined as a PDA where the stack has been replaced with a queue. Prove that a *Queue Automaton* is more powerful than a PDA. Prove that a *Queue Automaton* is not more powerful than a Turing Machine.

**Problem 3 [10 point]** Let  $L = \{\langle G \rangle \mid G \text{ is a } CFG \text{ with no useless variables}\}$ , where a useless variable is one that is not used in any derivation of a string of terminals. Give an algorithm to show that  $L$  is decidable.