Value Ordering Heuristics for Quantified Adversarial Constraint Solving

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Why Quantified Constraint Satisfaction Problems (QCSP)?

Quantified CSPs are a generalisation of the standard CSP in which the variables are in a fixed sequence and some of them are universally quantified. For each possible value of such variables, we have to find values of the remaining existentially quantified variables so that all constraints in the problem are satisfied. QCSPs can be used to model PSPACE-complete decision problems from areas such as model checking, planning under uncertainty and adversarial game playing.

We aim to develop Online-QCSP solving, which will use adversarial reasoning to solve real-time multi-participant problems, in which we are uncertain of what actions other participant(s) may take. Existentially quantified variables represent our choices and universally quantified variables represent those of the other participant(s). We would seek to find a full assignment to the problem, while the other participant(s) would seek to cause a domain wipe out.

Value Ordering Heuristics

The first step towards Online-QCSP solving is to be able to evaluate the value of the current state of a partial solution, in order to decide what value to assign the next variable taking account of your opponent's possible future choices. As initially worked on developing value ordering heuristics for *standard* QCSPs. These heuristics were tested against QCSP-Solve, a state of the art QCSP Solver which uses lexicographical value selection.

Two families of Value Ordering Heuristics were developed.

Adversarial Value Ordering

These heuristics use a **Minimax** approach to reasoning. For **existential** variables we assume that we wish to find a solution so choose the value most likely to lead to one. For **universal** variables we assume the opponent chooses the best value for themselves, which is the one most likely to lead to a failure.

We estimate how likely a value is to lead to a solution by multiple methods: based on how much support a value has with values in the domains of future variables, or how large the future domains are after propagation when a value is assigned.

Adversarial value ordering heuristics are most suited to solving tough QCSP problems which have very few possible solutions. **DGP** is an adversarial heuristic.

Pure-Value Value Ordering

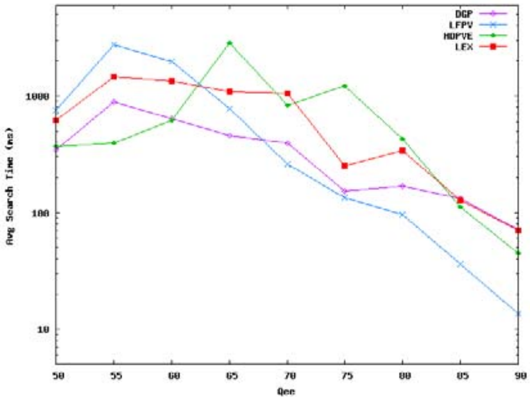
These heuristics exploit a technique of the QCSP-Solve solver known as the Pure Value Rule. This rule reduces the running time of the solver significantly because it allows some of the universal variables' values to be pruned from their domains during search.

These heuristics seek to maximise the number of pure value prunings which can be performed by QCSP-Solve.

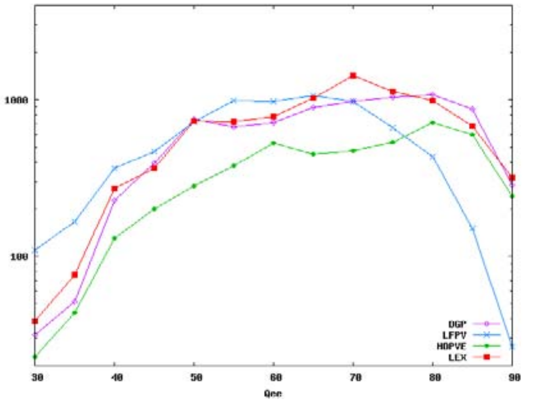
Pure-Value value ordering heuristics are most suited to easier problems which are likely to have many possible solutions. **LFPV** and **HDPVE** are pure value heuristics.

Experimental Results

We tested on two classes of problems, 3-Block problems and Interleaved problems. 3-Block problems are harder and interleaved problems are easier.



3-Block Problems



Interleaved Problems