Dynamic Step Size Adjustment in Iterative Deepening Search

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If an iterative deepening search (IDS) procedure has the property that solutions at a given iteration are also found at later iterations, it is possible to skip iterations without loss of correctness. We examine the conditions required for skipping to be worthwhile and give an algorithm for dynamically adapting the skipping to the behaviour of the search procedure.

We consider the problem f with solution π, written $\pi \models f$. If a solution is found during IDS at depth i, we write $\pi \models_i f$. We write $T(f, i)$ for the time taken for the ith iteration. We make the following simplifying assumptions:

- If f has a solution, this solution may be found by iterative deepening search to some depth k: $\pi \models f \rightarrow \exists k \cdot \pi \models_k f$
- If f has a solution at depth i then it is solvable at all greater depths: $\pi \models_i f \rightarrow \forall j \geq i, \pi \models_j f$
- $T(f, i)$ is monotonically increasing with i: $\forall j \geq i, T(f, j) \geq T(f, i)$

To decide on the size of a step to be taken, we consider the circumstances under which a particular step size will save time overall. Suppose we are currently at depth i during the IDS. It is preferable to solve $\pi \models_{i+\Delta} f$ next rather than the sequence $\forall_{j=i..n} \pi \models_j f$ iff $i + \Delta > n$ and $T(f, i + \Delta) < \sum_{j=i+1}^{n} T(f, j)$. The point of comparison, n, is chosen by a simple heuristic found in testing to be sufficient: the first solution of f is equally likely to lie at any depth $k, 0 \leq k < \infty$, so we take $n = i + \lceil \frac{\Delta}{2} \rceil$.

To construct the algorithm, we approximate $T(f, i)$ as an exponential ba^i, which is appropriate for many possible applications including bounded model checking. We determine the a and b using standard statistical methods on the past behaviour of the search, and hence choose a maximum Δ which satisfies the conditions above. This gives us the following algorithm:

- Initialise: $a, b \leftarrow \infty$, current depth $i \leftarrow 0$, list of past behaviour $B \leftarrow []$
- Until a solution is found, loop:
  - Solve $\pi \models_i f$, recording the time taken in t
  - Append the pair $\langle i, t \rangle$ to B
  - Use best-fit on B to estimate a and b
  - Choose Δ such that $ba^{i+\Delta} < \sum_{j=i+1}^{i+\lceil \frac{\Delta}{2} \rceil} ba^j$
  - $i \leftarrow i + \Delta$

Our preliminary experimental evaluation demonstrates the efficacy of this method on bounded model checking problems; however, other iterative-deepening-style problems must be tried in order to determine the generality of the heuristic chosen.