Heuristic Search Based Soft-Input Soft-Output Decoding of Arithmetic Codes

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Recent research (e.g. [1]) has shown that by introducing a "forbidden symbol" (FS), one can significantly improve the error resilience of the decoding of arithmetic codes (ACs) when the bitstream is transmitted over error prone channels. The FS was used to facilitate continuous pruning of possible source paths and deemed necessary because the number of such paths can grow exponentially. However, the FS is an extra overhead whose introduction in many applications is prohibited or highly undesirable.

In this paper we took a different approach to error resilient AC decoding. Instead of an FS, we utilized heuristic search algorithms (HSAs) in artificial intelligence ([2]) for finding the minimal-weight path through directed and non-negatively-weighted graphs. HSAs were designed to efficiently deal with exponential growth of paths without the assistance of an embedded "error" flag such as the FS. Instead, an HSA maintains a list (*Open*) of nodes that ***might*** need to be examined, and, starting from only the root node (r) in *Open*, removes the most "promising" (based on a pre-determined metric) node n from *Open*, and checks if n is a solution. If yes, the algorithm exits; otherwise, it adds all children of n that are not currently in *Open* to *Open*, and records the concatenation of the optimal path $p(r, n)$ from r to n and the edge $e(n, c)$ between n and the child c as the current optimal path $p(r, c)$ from r to c, along with the value of optimality metric for this path. For any child c that is already in *Open*, the algorithm checks if the recorded "optimal" path to c should be updated to $p(r, n)+e(n, c)$. This process is repeated until a solution to the target problem is found. It can be proven that ([2]) if the optimality metric depends only on the weights of the edges between nodes that are already examined, the optimality of the solution found by such an HSA ("optimal search") is guaranteed. Otherwise, if the optimality metric also depends on estimates of the weights of unexamined edges (i.e. "heuristic information"), the algorithm ("heuristic search") may not always find the truly optimal solution, depending on the "quality" of the heuristic information. By using "good" heuristic information, the complexity of the search can be significantly reduced while maintaining the "quality" of the solutions found.

The paper described an optimal search based and a heuristic search based decoding algorithm for ACs and compared their performance and complexity with the traditional "hard" bit based AC decoder. Simulation results showed that both algorithms easily out-performed traditional "hard" bits based arithmetic decoder, while the heuristic search based algorithm achieved a very good tradeoff between performance and complexity.

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