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Answering Queries Using a Time Machine

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Introduction

What if we could send a message back 1 second in time?

That is, what if closed timelike curves (CTCs), existed and could be used by computers? The implications of such phenomena for computation have been previously studied [see references], and results have been obtained only for machines sending information back a polynomial amount of time to answer yes/no questions.

Can CTCs answer general queries in 1 second?

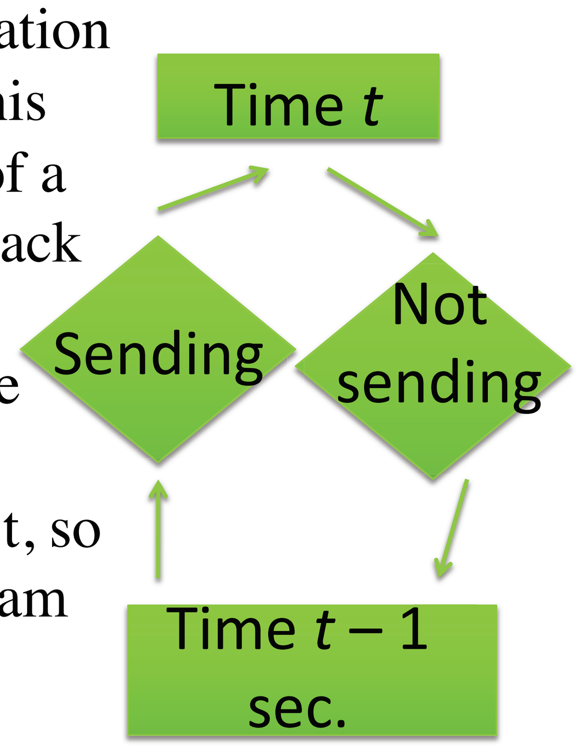
What about paradoxes?

Before answering this question, we must deal with some paradoxes…

Grandfather of second author (photo by Goodrich, 2009)

For instance, in the ***grandfather paradox***, a man travels back in time and kills his grandfather. The problem is that this man then is never born, so he can't go back to kill his grandfather. But if he can't go back in time to kill his grandfather, … [Cue infinite loop.]

We can just as simply construct an equally upsetting ***computational grandfather paradox*** simply by thinking of the man and his grandfather in terms of information and algorithms. The man and his grandfather are two branches of a program. The program sends back a message one second in time instructing itself not to send the message back in time in one second. So the program doesn't, so the program does, so the program doesn't…etc.

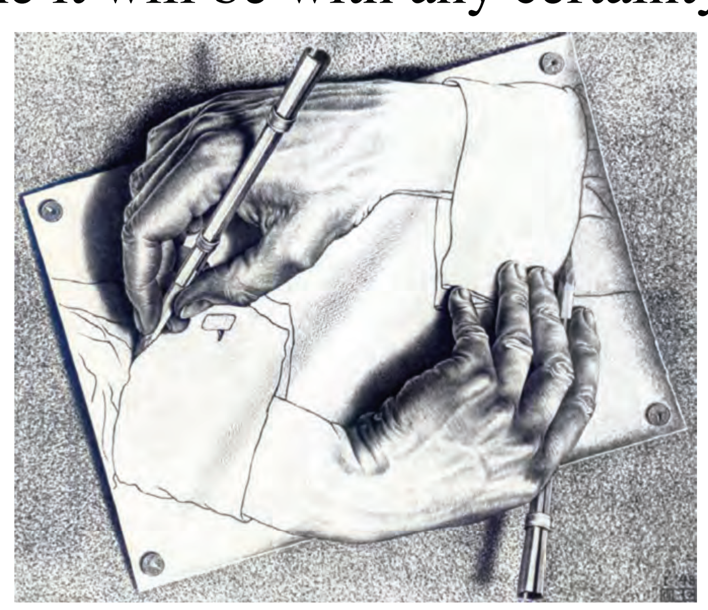


Work-Arounds & Anti-Paradoxes

Deutsch [1991] proposes a simple solution to such paradoxes: Assume ***nature assigns probabilities*** to timelike causalities. E.g., the man goes back to kill his grandfather with probability ½ and is never born with probability ½. Since every Markov process has a stationary distribution, there is a fixed point probabilistic solution to every such CTC causality loop.

(image courtesy of squacco)

Of course, such a fixed point might not be unique, which allows for ***anti-paradoxes***: for instance, in the ***Shakespeare anti-paradox,*** a time traveler goes back in time and dictates *Hamlet* to Shakespeare (before he has written it), who then writes *Hamlet*, so that years later the time-traveler can go back and dictate it to him. (So, who wrote *Hamlet*?). Our approach allows for this. So, for example, if there are multiple possible answers for a particular query, our algorithm will pick one of them with extremely high probability, but we can't say which one it will be with any certainty.

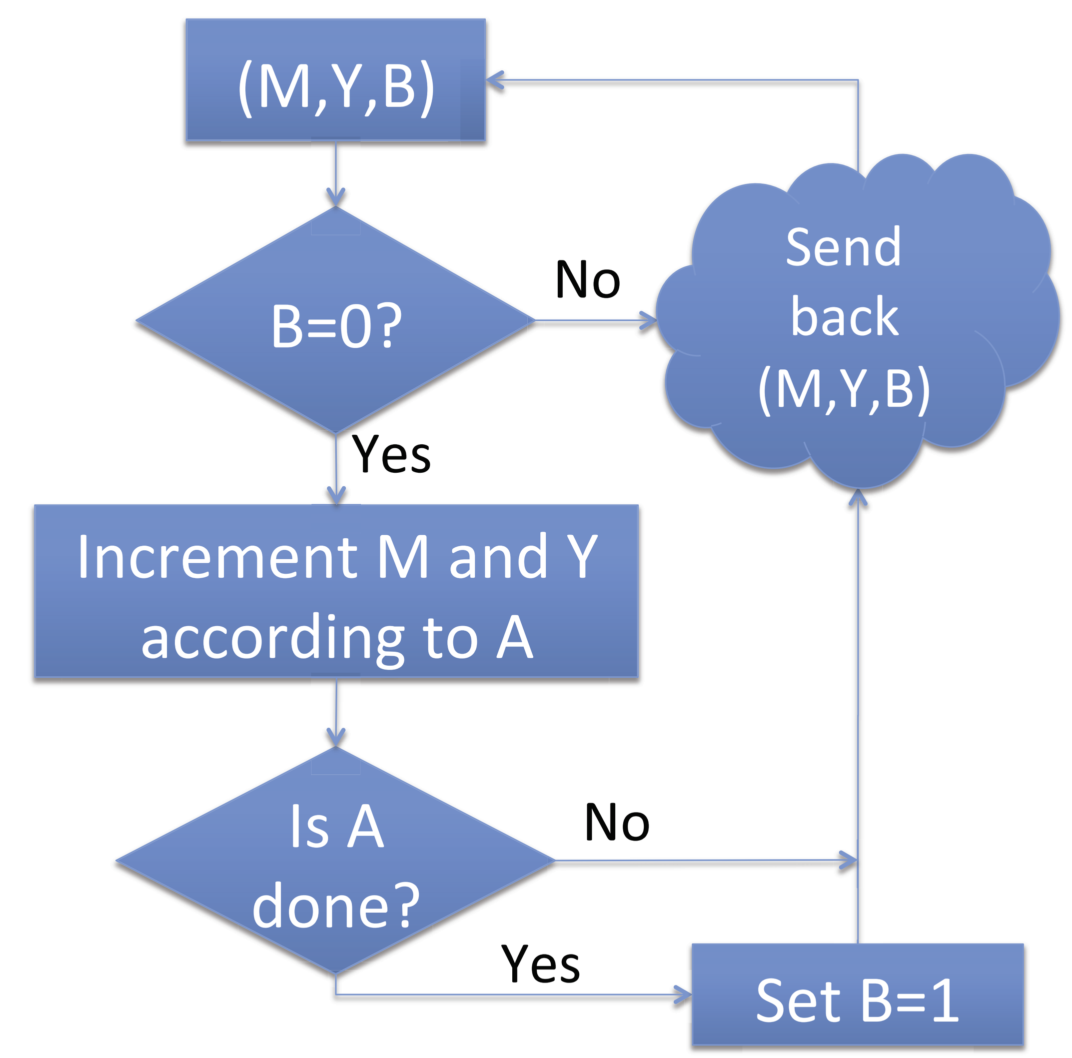


Escher's etching is intuitively disturbing but logically consistent. (Escher, 1948)

Main Result

Aaronson and Watrous [2009] (see also Aaronson [2011]) show that PSPACE=P with a CTC, but only for yes/no problems. (Note: self-reducibility doesn't apply to CTCs, since we cannot "iterate" them like conventional algorithms.)

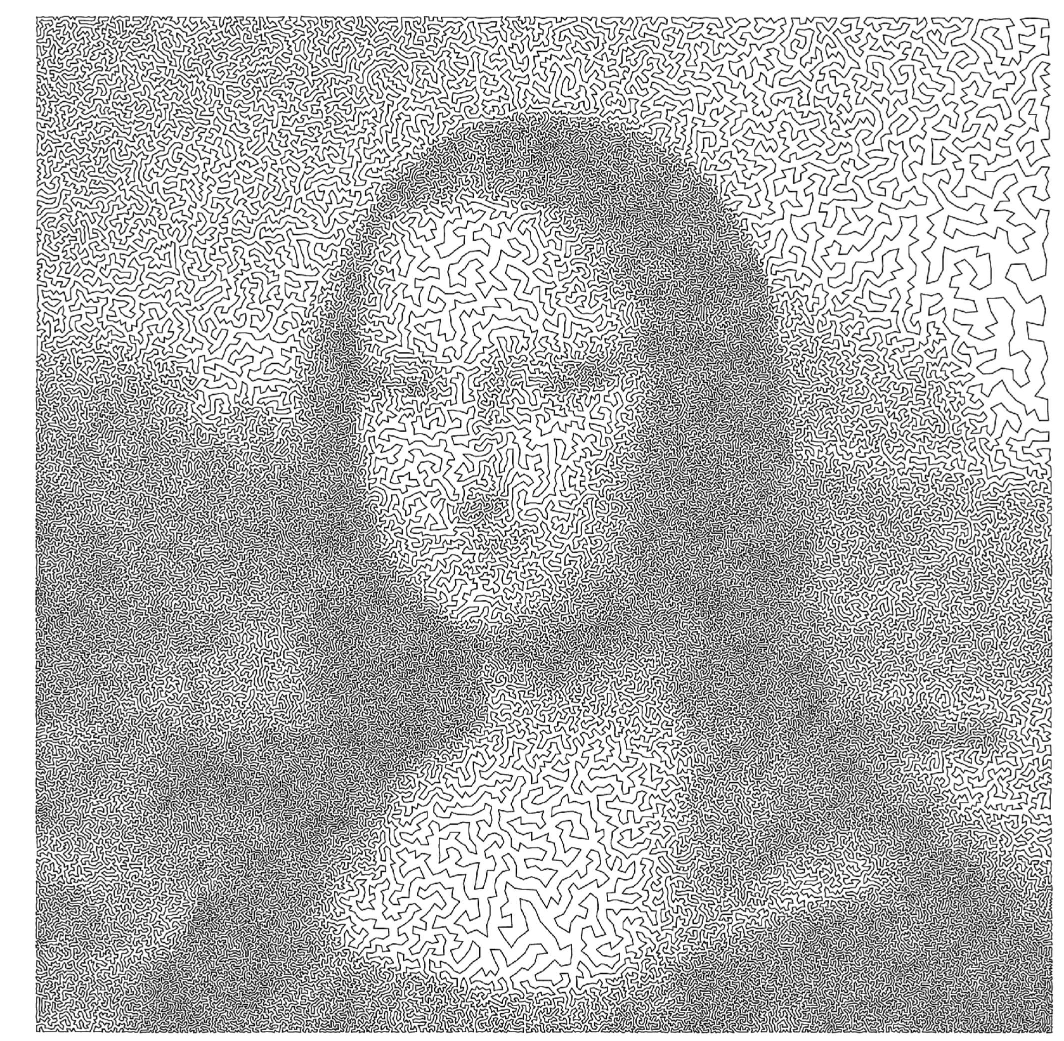
Our solution: Let ***A*** be a PSPACE optimization or search algorithm. Simulate ***A*** using a CTC, with each step of the simulation involving the CTC to send back the result of one step of a computation, whose state is maintained by a tuple, (*M,Y,B*), where *M* is the contents of ***A***'s memory, *Y* is a representation of a potential solution, and *B* is a bit to indicate that this is a correct solution. If *B*=0, then can increment *M* according to the algorithm ***A*** stored inside *M* (including a PC counter that represents the step we are on), and also including an updating of *Y*, and if this is the last step in the algorithm ***A*** an update to convert *B* from 0 to 1. If *B*=1, on the other hand, we just send the current state back in time. The probability will only send back the final answer with high probability and every other state with very low, but non-zero probability.



Applications

There are several applications of such an approach, which yield 1-second, i.e., $O(1)$-tiime, Monte Carlo algorithms for a number of problems, which succeed with very high probability.

- Find a subset, S, of a given set, X, that satisfies a Boolean formula, F, if it exists.
- Decrypt a deterministically encrypted message, C, without knowing the key that encrypted it.
- Find an optimal Traveling Salesperson Tour.



From https://www.simonsfoundation.org/quanta/20130129-computer-scientists-take-road-less-traveled/attachment/mona-lisa100k/

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