

Mathematical Definitions of Time Machines: A Multidomain Survey

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Abstract

This document defines 'time machines' across multiple mathematical and theoretical domains, including general relativity, computation theory, and information theory.

1. Introduction

Time travel is often treated as a fictional trope. However, various scientific and computational frameworks do offer formal definitions of time machines.

2. Time Machines in General Relativity

Definition: A spacetime manifold (M, g) admits a time machine if it contains a closed timelike curve (CTC).

Formal: Let M be a Lorentzian manifold. A time machine exists if there exists a smooth map $\gamma: S^1 \rightarrow M$ such that γ is timelike.

Examples include the Gödel metric, Tipler cylinders, and certain Kerr geometries.

3. Time Machines in Computation Theory

Definition: A time machine is a Turing machine augmented with a time oracle.

Formal: Let TM^T be a Turing machine with access to an oracle T such that $T(t, x)$ returns the value of x at time $t \neq \text{now}$.

This model underpins retrocausal algorithms and speculative computational strategies where future outputs affect current inputs.

4. Information-Theoretic Time Machines

Definition: A time machine is a system that injects temporal information across entropy gradients.

Formal: If H_t is the entropy at time t , and information I_T is injected, then:

$$H_t \rightarrow H_{t'} = H_t - I_T$$

This model applies in Bayesian updates and quantum retrocausal models where information affects prior states.

5. Causal Graph Model Time Machines

In causal diagrams, time machines are edges that violate acyclic structure.

Formal: Let $G = (V, E)$ be a DAG representing causal structure. A time machine exists if there is a path from v_{t2} to v_{t1} .

Such models are used in counterfactual reasoning and temporal feedback in AI systems.

6. Taxonomy Summary

- GR Time Machines: Closed timelike curves
- Computational Time Machines: Oracle-based TM with time queries
- Information Time Machines: Systems with retrocausal entropy shift
- Causal Time Machines: Directed edges from future to past

7. Conclusion

Time machines are not a singular concept, but a family of models with unique domain constraints. This survey provides a formal overview of these concepts across multiple domains.