From Clues to Causal Chains: Constraint-Driven Event Reconstruction

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Formal Modeling in Digital Forensics

- **Event reconstruction** reasons about past actions performed within a system [3].
- While **formal models** of digital systems allow for precise event reconstruction, they require **complete system knowledge** and involve **costly computations** [3]. To tackle these challenges, several approaches have been proposed, including:
  - Defining properties of evidence to focus on the **specific reconstruction** problem: while an action's **characteristic** evidence (relative to a set of alternatives) consists of those observable traits that are produced exclusively by that action [1], observation of an action's **sufficient** evidence guarantees it's occurrence, and the absence of an action's **necessary** evidence refutes its occurrence [4].
  - Implementation of **computational tools**: proof-of-concepts modeling in formalisms equipped with model-checking [4, 5, 8].

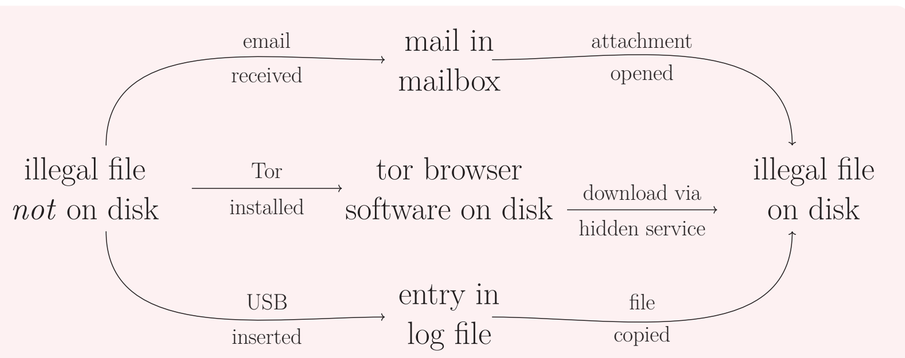
Automated Planning to the Rescue?

Approaches assume the existence of a formal model of the system with complete information. The **construction** of such models and **efficient reasoning** in the context of **partial knowledge** are not addressed.

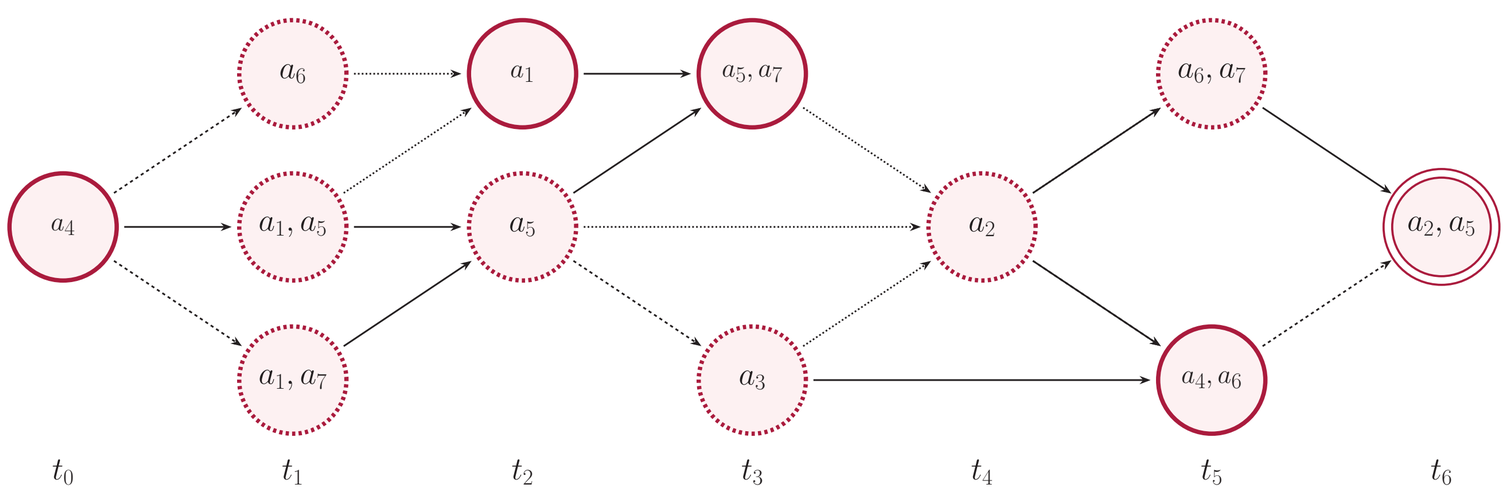
Background on Automated Planning

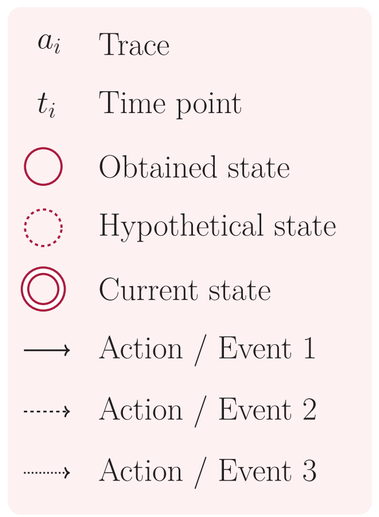
- Automated planning is a **well-established research area** with a substantial theoretical and practical foundation [2, 7].
- A **planning problem** consists of an input and a question to be solved:
  - *Input*: states (the system can be in), initial states (starting states of the system), actions (characterizing the transitions between the states), and goal states (what states we want to obtain)
  - *Question*: Can we find a combination of actions that allow us to reach one goal state from one initial state?

Planning Problem: Provenance of an Illegal File on a Disk



Hypotheses as Combination of Events: Does Your Hypothesis Explains all Traces?





Planning Problems to Reconstruct Events

- We build on the logic framework of automated planning [6] to solve the specific reconstruction problem [1].
- We express **artifacts as propositional variables** and **time points as valuations** over the set of artifacts.
- We define **events as transitions** between time points and characterize them by their **pre-conditions** (the conditions to be applied) and **post-conditions** (the effect of being applied).
- Utilizing logic programming and SAT-solving, we address planning problems that encompass all (or a subset of) acquired traces, thereby **implicitly constructing a model** of the forensic scenario.

Any Benefits for Digital Forensics?

- Introducing automated planning provides rigorous tools to:
  - **Evaluate hypotheses**: Do they cover all traces and the current state?
  - **Identify hypotheses**: Can we find a solution to a planning problem?
  - **Discover clues**: Can we reveal traces aligned with our hypotheses?

Another Formalism: Do We Really Need It?

Defining event reconstruction as a planning problem places it in a broad research field and **unifies past approaches**, potentially aggregating their insights. Yet, only simple examples have been modeled, leaving open whether this approach yields more insight than existing techniques.

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