How to Reuse Knowledge about Forensic Investigations

By

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How to Reuse Knowledge about Forensic Investigations

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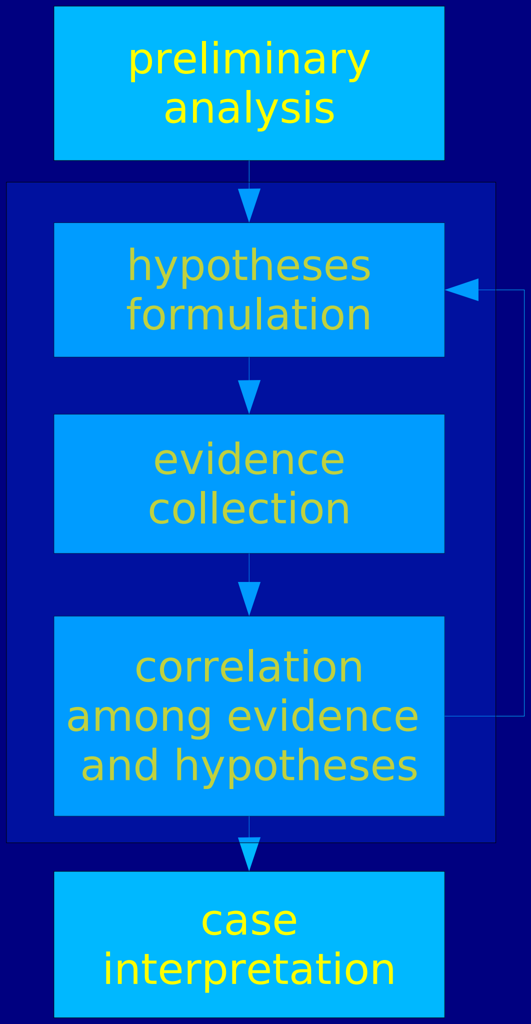
Motivations

- computer forensics investigations are complex because of the nature of digital evidence (volatility and skilled interpretation)
- the investigative process, in order to be presented in court, must be *sound* and *complete*, as much as possible; often every detail counts
- there are common *investigative patterns* that could be exploited to ease the work of investigators

Goals

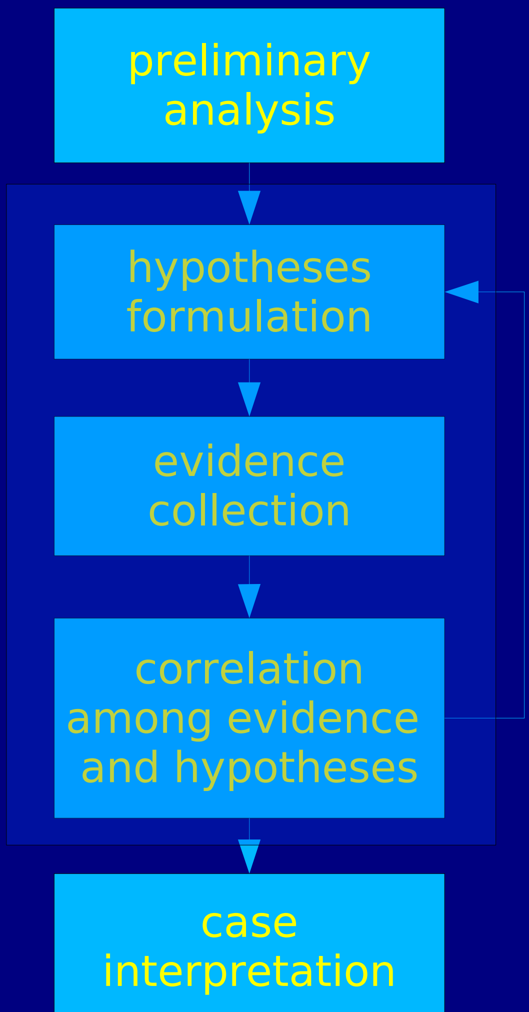
- represent the logical process followed in the proof of a thesis: *critical thinking*
- record collected information in a way that ease quality assessment
- organize past experience to foster knowledge sharing among forensic experts
- produce reusable forensic knowledge to be used as support during investigations

The investigative process



- preliminary analysis of the case
- formulation of hypotheses on the state of the world that caused the case
- collection of evidence on the basis of these hypotheses
- correlation of actual evidence with hypotheses

The investigative process



- revision of hypotheses: *abduction*
- repetition of the process until the consistency state of the knowledge about the case is acceptable
- interpretation, *by the investigator*, of the hypotheses against the collected evidence

A Cartesian approach to manage the complexity

1. *evidence*: nothing that is not clear and evident can be accepted
2. *analysis*: a complex problem should be decomposed in easier parts
3. *synthesis*: a decomposed problem has to be recomposed, verifying every partial solution
4. *enumeration*: review the whole process to verify the *soundness* and *completeness*

Principle of evidence (1)

- facts, observations, real things (data) to argument in favor or against a hypothesis
- conclusions have to be drawn providing tangible data
- evidence and its relevance is *context sensitive*

Principle of analysis (2)

- complex arguments ought to be separated in small ones
- the initial hypothesis is decomposed in sub-hypotheses:

$$H \rightarrow H_1, H_2, H_3, H_4, \ldots, H_n$$

- "," is not a logical connective and "$\rightarrow$" is not a logical equivalence

Principle of synthesis (3)

- recomposition of the partial solution of the decomposed problem
- from a forensic viewpoint: “collecting information to prove or disprove the occurrence of an event in the real world”

$$H_i \Rightarrow E_1, E_2, E_3, \ldots, E_n$$

- “$\Rightarrow$” denotes the application of tests in order to evaluate the hypothesis

Principle of synthesis (3)

- every evidence collection test will lead, if applicable, to a success or a failure
- the set of applicable tests is by no means complete
- sometimes highly relevant tests cannot be performed
- the strength of each test and the correlation among several of them is not a constant but context sensitive

Principle of enumeration (4)

- by making the process explicit is possible to assess the quality of the whole process
- reuse of past experience in analysis and synthesis decreases the possibility of human errors and omissions

Collected information can be organized as *forensic graph*

Forensic graph

$$FG = \langle H, E, F_h, F_e, w \rangle$$

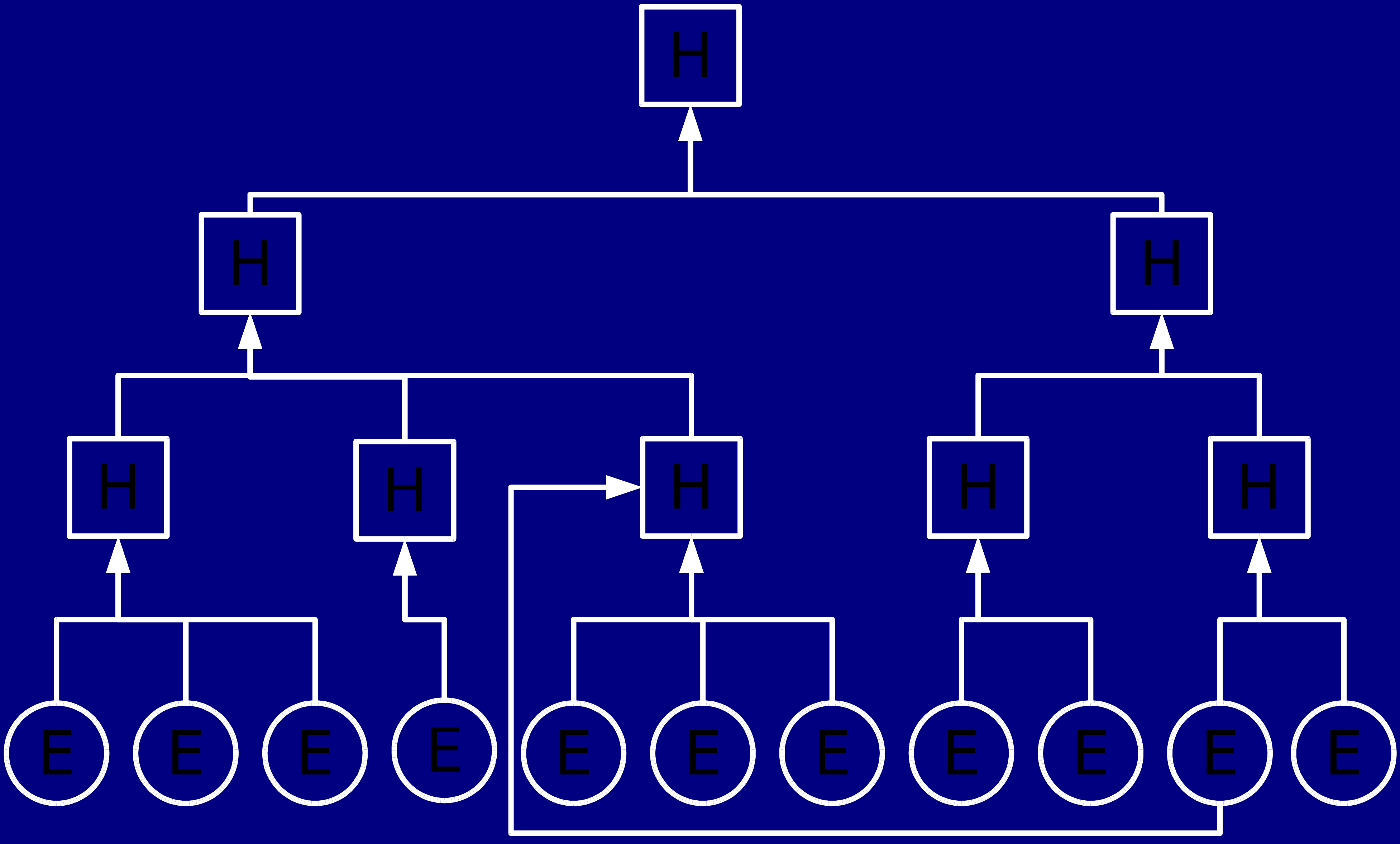
A DAG where:

- H set of hypotheses
- E set of evidences
- F_h decomposition relation ($F_h \subseteq H \times H$)
- F_e association relation ($F_e \subseteq H \times E \times w$)
- w weight of evidence ($w \in \{+, -, ?\}$)

Forensic graph

- used to represent all the knowledge acquired over the time
- hypotheses and evidences are represented in natural language
- expresses the relations among hypotheses and evidence relevant for their validity
- every case is instantiated in a *case graph*

Forensic graph



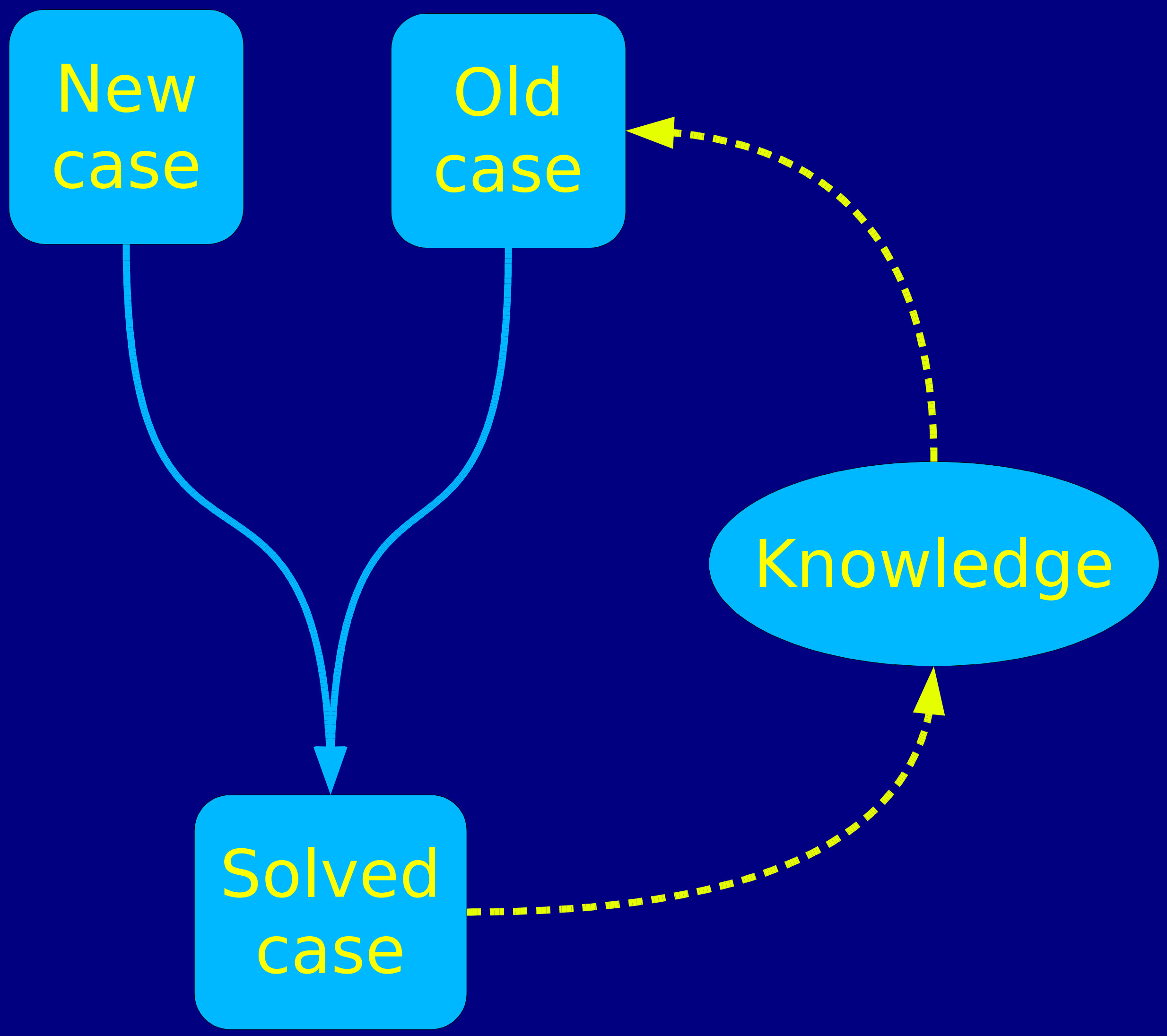
Case graph

- case graph models logic behind the detective's analysis in a specific criminal case
- a new graph is built using only the hypotheses and evidence related to the current context
- the weight of evidence expresses how evidence affects an hypotheses (corroboration, contradiction or the test was not performed)

Learning

- during the construction of case graph new hypotheses can be formulated
- new link among hypotheses and evidence can be discovered
- forensic graph is updated to reflect the new experience
- current experience will be available for future case

Reusing past experiences and learning



An example

H: email account **`bob@domain`**, registered by user *Bob*, has been used to send a harmful message *M*, to user *V*. *Bob* is the author of *M* and its sender.

An example (hypothesis decomposition)

H_1: *Bob* has sent message *M* from his computer *C*

H_2: sendmail, the mail transfer agent installed on *C*, has been configured to use **`bob@domain`** as the **`From:`** header

H_3: when *M* was sent (*T*), *C* has been in use

H_4: when *M* was sent (*T*), *C* was connected to the Internet

H_3: when M was sent (T), C has been in use

E_1: are there files modified, created, deleted, accessed at time T?

E_2: are there files that contain information about user activity (browser history, email-client recent file list, ...) at time T?

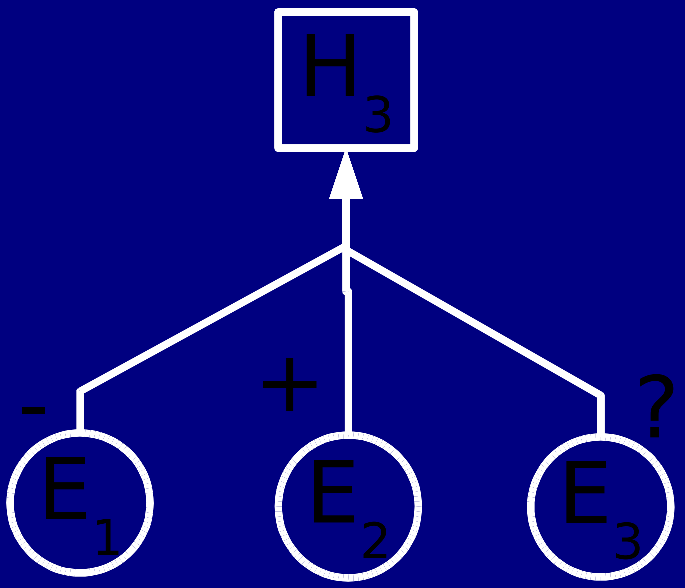
E_3: are there files that contain information about system activity (events logs, applications logs, ...) at time T?

H_3: when M was sent (T), C has been in use

E_1: not found

E_2: found

E_3: N/A (logs were encrypted)



Is evidence conclusive or inconclusive?

The answer is left to the investigators!

Limitations

- it is neither possible to express nor to evaluate how much an evidence influences an hypothesis: *inferential drag*
- expression of hypotheses and evidence in a natural language limits automatic search inside knowledge

Conclusions

- argumentations supporting a hypothesis are open to criticism
- representation through a graph renders knowledge reusable (even of subgraphs)
- knowledge can be improved as investigation experience grows

Future works

- we are implementing a tool that applies our approach to be used as a guideline both for detectives and attorneys
- provide a structured language to describe evidence and hypotheses in order to process them automatically
- estimate the relevance of hypotheses studying the outcome of previous and concluded case: *analysis of causality*

Questions and suggestions are welcome...