CATS: Cognitive Analytic Trail System

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Abstract
Analytic systems provide insights to decision makers based on data. Conclusion quality depends on the input data and the reasoning steps made by analysts during exploration. This paper presents CATS, a system able to: (i) Store and leverage information about analytical processes conducted by analysts; (ii) Improve the quality and confidence on analytical reports, by improving how well analysts recall their activities; (iii) Provide ways of comparing different analytical reports; (iv) Help with the dissemination of best practices within analytical teams; (v) Produce the provenance of analytical reports. The use of CATS is illustrated through an example of tracking the work in WISE (Weather InSights Environment) a real tool that combines forecast and observed environmental data to provide an integrated platform to make informed decisions.

1 Introduction
Analytic systems are utilized to create, test, and visualize hypotheses considering domain data. Knowledge gained from these tools is used to make decisions inspired by real data. The analytical process often involves the use of different systems and can take hours or months to be finished due to the complexity of the involved tasks. At the end of the process, the analyst typically provides a report about the discovered knowledge and, occasionally, the followed reasoning steps. Relaying the actual reasoning steps is important in order to explain the findings, to evidence what have been done, to find out the strategies/methods used by the analyst, to reproduce the reasoning process for future analyses and to use them as a roadmap in other analyses.

Usually, analysts are not able to recreate their reasoning steps in details, which results in unintentional errors and gaps when reporting their work. Several approaches are able to capture and store the interaction data that are typically low-level events, like mouse click and key-press, with semantically meaningful tasks. There are several approaches to automatically capture historical data and make available an interface component that allows users to manually add notes associating low-level events with high-level tasks (Gotz and Zhou 2009) (Denisovich 2005). Some of the systems are also able to provide interfaces where the analysts can visualize their sequence of events/tasks – called trails (Lu et al. 2011) (Shrinivasan and van Wijk 2008).

Our goal is not to create a new (visual) analytic tool/system, like SAS Visual Analytic or Tableau. Neither to create an analytic trail technology as part of an analytic tool, such as (Lu et al., 2011), or a system simply able to capture and store the interaction between an analyst and analytic(s) system(s), such as CrazyEgg and MouseFlow.

This paper presents the cognitive analytic trail system (CATS). It is a generic system since it is not tied to any particular visual analytic system. It is a cognitive system since it assists the analysts on their reasoning processes and helps others on understanding them. It is an analytic trail system since it provides mechanisms to visualize, annotate and compare analytic trails. Our approach is able to assist the analysts and decision makers by: (i) Providing a mechanism to associate low-level events with tasks and to annotate these tasks; (ii) Suggesting new tasks and goals, the next event, the proper annotations and associations between events and tasks; (iii) Providing visualization tools to visualize trails; and (iv) Comparing the recorded trails and helping on understanding the similarities and differences among them.

The remainder of the paper is organized as follows. Section 2 presents an overview of CATS architecture, while Section 3 details its components. Section 4 presents an example of an analytic system supported by CATS. Section 5 presents
the related work highlighting CATS contributions. Finally, Section 6 presents the conclusion and some future work.

2 CATS in a Nutshell

CATS' architecture is composed of four connected components (Figure 1): provenance manager, task manager, trail visualizer, and cognitive advisor. CATS can be used by any analytic system requiring assistance for its users.

![CATS architecture diagram]

**Provenance Manager** stores provenance data and provides such data to the other three components. **Task Manager** provides user interfaces for decision makers to define goals and tasks to be conducted by analysts, and to show provenance data. The analyst can associate provenance data, typically low-level events, with more high-level semantically meaningful tasks. The analyst can also annotate such events/tasks with textual information. **Trail Visualizer** provides user interfaces to visualize and compare stored trails, and to visualize executed low-level events information, tasks and events associations etc. **Cognitive Advisor** component is responsible to understand and reason over the trails. It learns from the collected provenance data and provides relevant information to the Task Manager and the Trail Visualizer components to help the analyst to perform his/her tasks.

CATS provides two interfaces for instrumentation of an Analytics System (here named as source system): a RESTful API for storing and consuming provenance data (Provenance Manager), and a standalone application for tracking user actions (Task Manager). Provenance codifies user actions and data transformations that culminate in a result or, more specifically, an analysis. It is a premise that the analytic system must be able to capture the provenance data related to the interaction between the analyst and the system, and to call the Provenance Manager services. In CATS, users can take two roles: analyst or decision maker. Users interact with CATS through the standalone application executed in tandem with their analytical systems.

3 CATS components

This section describes the four CATS components.

3.1 Provenance Manager

The Provenance Manager is a service that stores provenance data. Provenance is a kind of metadata that can be used to help determine the derivation history of a data product (Simmhan, Plale, and Gannon 2005). This type of information can give valuable insights into the quality of a given data product, such as who, when, and how it was derived. There are several types of provenance, such as prospective, retrospective, and insight or analytic provenance. Although there are standards to store prospective and retrospective provenance, such as PROV-DM, there is no standard for insight or analytic provenance. *Insight or Analytic provenance* is the extraction of user’s reasoning from interaction recordings (Nguyen, Xu, and Wong ) (Gotz and Zhou 2009).

PROV-DM is a W3C standard. It was developed to be a generic domain-agnostic data model, that allows translations from domain-specific provenance data to it. PROV-DM is composed of core structures and extended structures. Its core structure has three types: **Entity**, **Activity**, and **Agent**. **Entities** are data products whose provenance information are stored. **Activities** are data transformation tasks enacted over entities. **Agents** are responsible for executing activities, creating entities, or triggering other agents activities.

Provenance Manager uses PROV-DM as its data model. Being domain-agnostic model, it is capable of storing provenance from multiple source systems. The task of capturing the data is beyond the scope of Provenance Manager. The Source System is responsible to track users (analysts) actions, structure the capture data according to PROV-DM, and call the Provenance Manager services to store that data. The system is capable of handling actions with different granularities, i.e., source systems can send provenance data as low-level events (e.g., a mouse click) or high-level ones like task (e.g., a visualization started by the user).

3.2 Task Manager

The **Task Manager** component has two major responsibilities: (i) Support the definition of goals and tasks; and (ii) Support the correlation between lower-level events with tasks, and tasks with goals.

Goals are high-level definitions of desired outcomes for the analytical process and they are defined by decision makers. Goals are composed by tasks that are high-level steps to achieve the goals. Both goals and tasks are domain-dependent concepts, i.e., a particular goal holds in a specific context, and analysts and decision makers have to be familiar with the particular domain. This characteristic constrains automatic derivation of both goals and tasks.

The analyst can visualize the trail of events and tasks he is currently working on. In this mode, analysts can correlate events to tasks and tasks to goals. This is a crucial step because low-level events, such as mouse clicks or mouse motions, have poor semantics. Hence, the events and tasks associations allow users to easily recall their overall reasoning when creating their final report.

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8PROV-DM’s full definition can be found at: [http://www.w3.org/TR/prov-dm/](http://www.w3.org/TR/prov-dm/)
Analysts can also annotate tasks, events, and the relationships between events and tasks. These annotations can be used to capture the analyst insights for later use on, for instance, generating the report.

Task Manager is strongly coupled to the Cognitive Advisor component. The Cognitive Advisor advises the decision makers when they are creating goals and tasks by informing about similar goals and suggesting the tasks. It also advises the analysts during the execution of a goal by proposing tasks and events to be executed, by suggesting the association between events and tasks and by recommending annotations to tasks.

### 3.3 Trail Visualizer

The Trail Visualizer and Task Manager share the visualization of trails feature, but with different goals. The Task Manager focuses on managing future and current trails, while Trail Visualizer is a tool that uses stored trails for making analyses and comparisons.

Decision Makers can leverage Trail Visualizer to compare the work of several analysts to achieve a goal, while analysts can use this feature to improve the steps assigned to them. The Trail Visualizer also uses the Cognitive Advisor in order to advise decision makers and analysts on their task. For instance, the Trail Visualizer presents the trial patterns (e.g., similarities, outliers) identified by the Cognitive Advisor by highlighting the differences and similarities among trails.

Trail Visualizer may also work as a training system, presenting the user the steps she/he should/could take to accomplish a given task.

### 3.4 Cognitive Advisor

Cognitive Advisor is responsible to understand and learn from the data stored by the Provenance Manager, data that represents the interactions between analysts and analytic systems. Afterwards, it is able to generate hypothesis and recommendations, identify patterns, construct models (e.g., processes or probabilistic models) providing information that the other components may use to assist users.

The ability to understand the analysis being made and querying provenance data allow analysts to have deep insight into their own work. Composing existing functions and finding correlated process fragments allow the analyst to shortcut repetitive tasks; the same applies to the automation of some tasks. Through rule extraction, it is possible to identify rules that govern when a task or a particular process conducted by the analysts might evidence what users have made different interpretations about what happened or that different data were presented to the users.

Similar tasks related to different annotations can indicate that users have made different interpretations about what happened or that different data were presented to the users.

### 4 Example of CATS in Action

This example presents how CATS would act in to track the work in a real tool – WISE (Weather InSights Environment) (Oliveira et al. 2014). WISE is a solution that combines forecast and observed environmental data, providing an integrated platform to make informed decisions. One such scenario is evaluating alert severity. For instance, an alert fires in a region \( r_1 \) when the forecast or actual precipitation is higher than a limit \( t_1 \). Analysts are required to assess the severity of these alerts, e.g., verifying other parameters in the model in order to evaluate the overall meteorological conditions.

To assist this use case, WISE was instrumented to capture interactions users have with its graphical interface and the alerts subsystem. This provenance data is stored by the Provenance Manager. To track the assessment, a goal was created in Task Manager.

During the severity assessment of an incoming alert, CATS helps analysts by suggesting other parameters they should verify. Relevant parameters are found by Cognitive Advisor. Correlations are drawn by assessing what parameters are usually verified before a successful assessment. For example, in a good portion of successful alarms in similar conditions (region, type of geography, volume of precipitation), analysts viewed the amount of rain in the previous week. In this case, CATS would suggest the analysts should review the previous week’s precipitation levels. Successful risk assessments are made when the city’s response fits the severity of the situation, wrongful alarms can be very costly: unnecessary waste of resources when the risk is actual low, or endanger citizens lives when the risk is indeed high. Therefore, CATS suggestions have the goal of increasing the depth of analysis done during an assessment. When analysts are done with their assessment, they submit a report advising his/her superior as to the best course of action.

CATS aid the report evaluation by decision maker through exposing the provenance of all analyses, showing both data and process, and also presenting decision makers with historical perspective on this type of decision, using Trail Visualizer. This enables decision makers to evaluate the process performed by analysts in a comprehensive way. The parameters and process conducted by analysts might evidence what should be the final decision. For example, if the parameters and process conducted by the analysts, and annotations and analyses they report are similar, it indicates there is a consensus, and this supports the decision to be taken, leading to a higher degree of confidence in the final decision.

### 5 Related Work

In this section, we present some works related to our approach. We have divided them into tools able to: (i) Visualize, explore and understand data; (ii) Capture the interaction between the user and the system; and, (iii) Understand user behaviour.
The goal of visual analytic tools/systems, such as SAS Visual Analytic, Tableau, IBM Watson Analytics, and TabuVis (Nguyen et al. 2012), is to help users on data visualization and statistical analyses. Different from CATS, they focus only on the visualization, exploration and understanding of the data.

There are several tools able to capture the interaction between users and web-based systems, and others able to capture workstation activities. The majority are able to capture only mouse click, key-press and page changes, while others, for instance, are able to capture eye movement (CrazyEgg and Mouseflow) and also record facial expressions (Morae). In (Morae) and (Cowley et al. 2006) users are also able to add annotations to recorded information.

Lu et al. (Lu et al. 2011) present a tool to store analytic trails, i.e., a tool to capture the provenance of analytic processes. In (Gotz and Zhou 2009) the authors present an approach able to automatically associate low-level events (like mouse clicks and drags) that have poor semantics with high-level ones like tasks.

Analytic tools, such as Google Analytics and the ones presented in Glassbox (Cowley et al. 2006), StereoLogic, Aruvi (Shrinivasan and vanWijk 2008) and Harvest (Gotz et al. 2010) use the recorded information to understand users behavior. Google Analytics gives insights into web site usage and engagement. Glassbox’ goal is to leverage such information to capture/model existing processes and develop new tools to improve these processes. The same is true for StereoLogic. It records and measure the operations of employees to discover the process and improve the workflow. Aruvi presents a tool composed by three views: data view that supports the visualization of the data, knowledge view that records the analyst steps, and a navigation view that makes possible the navigation through the analyst steps. Harvest focuses on recording the visual analytic activities of a user in a given system to recommend a more effective visualization and to allow flexible adaptation of a user’s analytic process to new situations.

Different from such approaches, CATS focuses on advising users on analyzing and comparing provenance trails. It is able not only to store and annotate the interaction between users and systems, but also suggest the next step to execute, possible associations of tasks to events and task annotation. In addition, its users are not only able to visualize but also compare trails in order to find out similarities and differences. CATS is able to explain what the differences and similarities in the trails may suggest. In summary, CATS is a cognitive system that assists analysts in their daily analysis work, and help decision makers to take enhanced decisions.

6 Conclusion and Future Work
This paper presented CATS - a cognitive analytic trail system that provides mechanisms to visualize, annotate and compare analytic trails. We described its architecture and its four components: Provenance Manager, Task Manager, Trail Visualizer and Cognitive Advisor.

The related work analysis pointed out CATS brings new features. It contributes on advising the user when analyzing the stored provenance trail and when comparing different trails. CATS points out to the user next steps to execute, possible associations of tasks with events and annotations of tasks to be set. It enhances users work and provides mechanism that make easy to the user to generate high quality reports from the generated hypothesis, arguments, and evidences from the annotated trails.

As future work, we are further implementing and enhancing CATS components, and we are going to use it in real scenarios where analysts lacks CATS features. From those use cases, we will evaluate our proposal in qualitative and quantitative way.

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