Now This Changes Everything: Managing Provenance using Multimedia Narrative

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Abstract— **When dealing with an unexpected event we often need to understand why it occurred before we can make an appropriate assessment of the situation and respond accordingly. This can be quite difficult when dealing with large teams of autonomous robotic vehicles performing in dynamic unstructured environments. Here the human teammates may not be directly aware of each vehicle's situation and need to be provided with the appropriate context to make a suitable assessment of their situation. Our current work is exploring the use of automated Multimedia Narrative, or storytelling, to explain the nature, causes, and potential consequences of an unexpected event to a human supervisor of multiple autonomous robotic vehicles. This work uses the W3C PROV data model to map the provenance of information in the Allied IMPACT (AIM) C2 system, and identify the flow-on effects of unexpected changes. A structured narrative is automatically generated from the PROV model and tailored to suit the human supervisor's current information needs.**

I. INTRODUCTION

Traditionally, a team of human operators have been responsible for remotely controlling a single robotic vehicle. In such cases the human operators are directly immersed in the situation experienced by the robotic vehicle, and are readily able to deal with unfolding events. But, when more autonomy is introduced a single human may become responsible for a team of autonomous robotic vehicles, and that direct immersion, and consequent awareness of the situation, can no longer be achieved.

The Allied IMPACT (AIM) C2 system is being developed by an international team as part of The Technical Cooperation Program's (TTCP) Autonomy Strategic Challenge (ASC), to allow a single human operator to oversee a team of over a dozen heterogeneous autonomous robotic vehicles operating in a dynamic unstructured environment. In a complex C2 system such as AIM, a change in a single piece of information can have unexpected flow-on effects on the fused picture displayed, what operating constraints are applied to the robotic vehicles, what tasking options are available to the operator, and what the expected outcomes of these options may be. It is difficult for the operator to keep track of the effects of these changes, and understand what may have caused an unexpected change or action in the system.

A provenance tracking system has been developed in AIM to track the dependencies between the information flowing through the system. In order to understand the effects of any changes, the operator may need to switch context and associated mental model. To achieve this multimedia storytelling using a virtual human storyteller is used to 'set the scene' so that the operator can understand the context of an unfolding situation and make the appropriate decisions to achieve the mission goals [1].

II. MULTIMEDIA NARRATIVE

Storytelling, or narrative, is a common method employed by humans to effectively convey understanding of complex situations to human team mates. Narrative immerses the audience within a situation and allows them to understand the main events and actors, the important relationships between them, and what the consequences may be [2]. Multimedia narrative coordinates narration with other display modalities, such as images, video feeds, maps, animations, textual and graphical annotations to rapidly convey key features and relationships. Different display modalities can be chosen to convey the appropriate level of trust in the information provided. Virtual human storytellers can be used to provide affective cues through culturally appropriate behaviours to manage trust and convey uncertainty, risk, importance and urgency. In this case, the apparent emotional state of the virtual human storytellers needs to be appropriate to the cognitive and emotional state of the target audience in order to achieve effective engagement.

As with human interactions, narrative is not always the most appropriate method of conveying information. When the audience is already contextually situated, traditional approaches to visualization may be the most effective. Narrative may be appropriate when context changes are needed to correctly interpret the information provided. The level of detail provided in the narrative also needs to be tailored to meet the current information needs of the target audience based on their prior experience and interaction with the system, while maintaining the overall narrative structure that maintains the coherence of the information presented. Ideally the narrative should reduce to traditional visualizations as the audience becomes contextually situated.

III. NARRATIVE GENERATION

The narrative system we have developed as part of the AIM C2 system uses Rhetorical Structure Theory (RST) to provide a general framework for achieving coherence within a multimedia presentation. In this approach, each element in a multimedia presentation has a rhetorical relationship to another element that describes its narrative role. A presentation structured in this way forms a graph, or more precisely a hierarchical tree, that links down to the central conceptual element of the presentation. Various pruning strategies can be applied to the graph to produce narratives that are tailored to meet the current information needs of the operator. This structure ensures that a rhetorical relation still links every element of the pruned tree, and hence coherence is still maintained between elements in the reduced narrative [4].

IV. Provenance With Multimedia Narrative

The provenance of information in the Allied IMPACT (AIM) C2 system is tracked and recorded by a component that is connected to the central messaging hub. It listens to the many different components in the system as they interact and enact change. The provenance information is recorded using a PROV Python library[1], which implements the W3C Provenance Specification of the PROV Data Model [5]. The PROV data model allows recording the relationships between *entities* (things), *activities* (actions/events/tasks) and the *agents* (software components/vehicles) in the system, describing how things were created, changed or delivered. This PROV structure not only provides a framework for making assertions about the past, but in turn allows us to track the corresponding flow on effects of any particular change.

A Narrative-Provenance module takes the records captured in the PROV model and automatically constructs a narrative from them using the RST structure. Preliminary work has focused around generating a narrative for a particular event of interest. To construct this narrative, we follow the relationships from the event of interest within the PROV records to re-construct what happened, why and any corresponding flow-on effects.

In this use-case we examined a situation where an autonomous asset, a UAV, was tasked to carry out a surveillance mission and shadow a suspected hostile platform. During this mission another vehicle is autonomously re-tasked to provide a communications relay for the UAV. When asked for an explanation of the re-tasking event, the system looks at the provenance records and reconstructs the series of events that led to this. Namely, the system is able to reconstruct that as the UAV was shadowing the suspect platform and it began to move out of communications range. At this point a policy checking component detected an impending communications range violation and triggered an alert. A plan monitoring system then responded by requesting a communications relay to preserve the current UAV tasking. A task management system then called an automated play to enact the communications relay and to satisfy the policy by avoiding the violation. Finally, the system re-tasked an asset that was performing a background behavior to assist with the communication relay.

In the example above, the Narrative-Provenance generation is triggered when a request is made to explain an event of interest, in this case the Communications Relay being deployed. This event maps to a PROV *activity* (the Communication Relay) and the system then follows the relationships in the PROV structure to construct the Narrative and explain why the relay was enacted. The provenance showcases interactions between systems, responsibility flow behind actions, and the evolution of data entities. Currently a simple heuristic-based approach is used to traverse the PROV graph and map the PROV relations to an appropriate multimedia narrative. The system marks up the information about each *activity*, *entity* and *agent* using a template-based approach that maps the information to our RST structure and can then produce an explanation that can be tailored to the users' information requirements and displayed accordingly.

This simple example demonstrates how the provenance tracking system can be used to automatically generate a structured explanation of an unexpected event in the AIM system. While this example involves a single vehicle, the approaches used can be generalized to arbitrarily complex situations. Significantly, this approach allows tailored explanations to be dynamically generated without any prior knowledge of the dependencies within the AIM system, or the environment in which it is being deployed.

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