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What do we do now? Workflows for an unpredictable world

M. David Allen *, Adriane Chapman, Barbara Blaustein, Lisa Mak

The MITRE Corporation, 7515 Colshire Drive, McLean, VA 22102, United States

HIGHLIGHTS

- We examine workflows that support highly dynamic missions with real-world interactions.
- We consider situations when workflows must be adapted beyond the bounds of their original assumptions.
- Our goal is to support agile operations and pipeline sharing by choosing relevant substitute actions when assumptions change.
- We describe a series of suitability functions for discovering candidate alternatives, without the strong assumptions required by previous work.

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ABSTRACT

Workflow systems permit organization of many individual subtasks into a cohesive whole, in order to accomplish a specific mission. For many government and business missions, these systems are used to manage repetitive processes, such as large data-processing and exploitation pipelines. Government missions with strong interactions with the real world are extremely dynamic, as are all missions dealing with error-prone or changing data streams. We contribute a vision for discovery of new steps in adaptive workflow systems, suitability functions that can discover candidate alternatives, and a way forward for sourcing options for decision-makers, without the strong assumptions required by previous work. As data-processing workflows are shared, the sharing entities may find that certain parts of the workflow must be adapted to the new environment of mission. Extremely dynamic environments call for capabilities that support agile operations and pipeline sharing by making it possible to choose relevant actions when a situation invalidates the assumptions of current execution. We adapt some work in schema matching towards this problem, citing key differences between the two sets of challenges.

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1. Introduction

Workflow systems permit organization of many individual subtasks into a cohesive whole, distributing computation and workload, and organizing large and complex tasks to accomplish a specific mission. For command and control (C2) missions, workflow systems are used to manage large numbers of repetitive processes, such as tasking air assets within the context of an Air Operations Center (AOC), or to describe at a high level the overall steps that are necessary to perform complex operations such as Personnel Recovery or Civilian Disaster Relief. Workflows exist at different levels of abstraction; some may be very low-level, orchestrating primarily (or exclusively) interactions of computation services. Others may be at a much higher level to indicate the different business processes, swim lanes, and activities that large organizations must execute in order to accomplish a complex mission. We differentiate between workflow *specifications* that set out a prescribed plan of steps for a certain type of mission, and workflow *executions* that represent the actual steps taken to accomplish an assigned mission.

For missions with strong physical world interactions, such as those pursued by many of our US government sponsors and typical of C2 situations, workflow executions may be extremely dynamic. The US Government creates many workflows, at varying levels of abstraction, corresponding to mission plans. It is desirable that for more agile operations, a "closest" workflow specification can be chosen when a situation occurs, which can then be executed. For example, hazardous material (HAZMAT) operations frequently begin with a certain set of assumptions and encounter the need to change those assumptions substantially while operations proceed. Starting with initial eyewitness reports, the mission may begin with the assumption that a chemical spill is not producing hazardous fumes, only to find later that the assumption is incorrect, and additional supplies and/or medical resources are needed to triage exposed individuals. Similarly, [1] deals with the need to

* Corresponding author. Tel.: +1 703 983 7140.
E-mail addresses: dmallen@mitre.org (M.D. Allen), achapman@mitre.org (A. Chapman), bblaustein@mitre.org (B. Blaustein), lmak@mitre.org (L. Mak).

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adapt medical workflow executions as patient reactions manifest themselves.

Currently, when a workflow needs to be adapted, human operators do not have tools available to help them do this. Typically what they do instead is to rely on training and experience, going entirely "off-script" and coordinating actions via telephone and email. Training and experience are rich sources of options, and this work does not seek to minimize them or attempt to replace them. But relying solely upon them assumes that the human operator actually knows the complete possible set of steps from which to choose. This is not always the case, leading to a *discovery* problem.

1.1. Contributions

This paper outlines our vision for the *discovery of new and possibly unconventional alternative steps within adaptive workflow systems*. Using some knowledge of workflow specifications and historical workflow executions, the system we describe helps to discover options for decision-makers in difficult situations. We observe that when unexpected problems arise, one of the most common questions decision-makers wish to ask is "how have situations like this been handled in the past?" Our system seeks to recommend answers to that question, with the goal of integrating selected recommendations into the execution of important missions for government sponsors.

This paper also contributes a number of suitability functions that individually can discover candidate alternative steps, by exploiting available workflow-specific metadata. Additionally, we describe an approach for creating hybrid suitability systems; these draw on lessons from schema-matching research into hybrid matching systems [2] and augment that work with our suitability functions. The purpose of this hybrid suitability system is to stake out a middle ground between two extremes found in the existing literature: the purely unstructured, naïve text-matching approaches, and the highly-structured, formal model and ontology-driven approaches.

When a workflow needs to be adapted, how can we discover appropriate steps to complete the assigned mission? Dynamic situations greatly expand the number of eventualities a specification must take into account, often past the point of practicality. Even if specifications are built to anticipate many different eventualities, operational experience (e.g., in disaster response or military operations) shows that unanticipated situations often arise, necessitating a new workflow to execute the mission. The solution needed to adapt workflow executions goes beyond adding handling for new error conditions; when the workflow execution encounters a new situation, a new path to the final mission goal may need to be taken. Our work focuses on discovery of relevant steps to build flexible, adaptable, and responsive workflow management systems for missions like C2 that require adaptation to new real-world situations. There are quite a few existing technologies that seek to help decision-makers select an option, or make a good decision; we seek to recommend a basic set of options for consideration by decision-makers, without requiring the existence of an a priori model that describes the domain.

1.2. Motivating example

Consider a high-level workflow specification for a HAZMAT Cleanup mission, as shown in Fig. 1. Each of the steps within the HAZMAT Cleanup workflow specification itself supports a nested sub-mission and may be expanded into additional specifications. Fig. 1 shows both a workflow specification for the high-level HAZMAT Cleanup mission (Fig. 1(a)), and a specification for the "Identify Material(s)" sub-mission (Fig. 1(b)). We use this as a simple example to illustrate the connection with a higher-level mission; indeed a substantial information pipeline exists simply between "obtain sample" and "validate identification". We focus on the higher-level mission flow to illustrate how needs within and between such pipelines change. When a need to change the current workflow arises, our goal is to provide a new set of possible steps to enable a successful mission. In other words there is a Discovery and Ranking problem with respect to workflow activities.

1.3. Inflection points in workflows

Previous work has focused on very different methods for suggesting new activities. We characterize the approaches as follows:

- Deep characterizations of the workflow domain, such as in the form of ontologies [3–6].
- Comparison of structural [7–9] and behavioral alternatives [10–13]. These approaches are concerned mostly with finding changes to the workflow that do not alter the graphical structure, or change the final set of processes executed.
- Case-based reasoning over user annotations and labels [14,7, 15], [37].

In many C2 environments, these solutions are impractical. For instance, building ontologies to a level of specificity that helps workflow adaptation requires bounds around the domain that are impractical to establish for the broad and rich spectrum of C2 missions. Meanwhile, the use of structural and behavioral comparisons requires a rich set of pre-defined or often-executed workflows to compare against that currently do not exist. Finally, case-based reasoning relies heavily upon annotations provided by users and execution history that again does not exist in many problem domains. In particular, our government sponsors' workflows are typically fluid and open-ended in a way that makes heavy annotations by users, established ontologies, or structural comparisons to other workflows that are semantics-free and limit the viable options, non-existent. Yet, we do have some characterizations of the domains; we believe these can be leveraged to provide substantial information over and above what the naïve approach – a user creating a new activity from scratch – would have.

We focus on supporting users at the *inflection point*: the point in a workflow execution where an unforeseeable eventuality arises, and examine the assumptions behind the execution shift. We seek to build a system that can provide recommendations to the end-user about adaptive options, by consulting all workflow specifications in a repository. The specifications in the repository may range from those supporting completely unrelated and unlinked missions to specifications for explicitly linked missions. These adaptive options then become inputs to further analysis and the selection of a new course of action that will subsequently either temporarily modify the workflow specification being executed or cease its execution altogether in favor of a substitute workflow specification. Note that newly adapted specifications are added to the corpus of available workflows. Even if these new specifications are never directly used again, they may reflect important lessons learned and suggest the need for new plans for the next crisis.

1.4. Approach

Fig. 2 illustrates our approach with a simple example for illustrative purposes. While many of our sponsor scenarios contain considerable complexity, we choose this example for pedagogical purposes to avoid the necessity of a longer description of the specifics of mission-focused information pipelines. Suppose that the specification within the workflow for "Call Department of Environmental Protection (DEP) to assist" uses a cell phone, but during a specific execution, the cell phone does not work—this inflection point calls for an alternate step. The specification for "Medical

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