Simulating Variance in Socio-Technical Behaviours using Executable Workflow Fuzzing

Completed Research Paper

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# Introduction

*Socio-technical systems* are large scale, complex models, representing the interactions between a diverse set of actors including individual technical artifacts, human operators, organisational structures (El-Hassan & Fiadeiro, 2007; Sommerville & Dobson, 2008; Susman, 1976). The behaviour of such systems are influenced by a complex interplay of factors, including formally defined business processses, legal or regulatory standards, technological evolution, organisational culture or norms and interpersonal relationships and responsibilities \citep{bade07structures,pentland05organisational}. Examples of such systems with complex workflows involving multiple actors include emergency vehicle dispatch \citep{robinson96limited}, electronic voting systems \citep{bryans04towards,lock07observations}, patient care in a neo-natal unit \citep{baxter07evaluating} and electronic stock exchange infrastructures \citep{cftc-sec10findings}. Systems of this form confound traditional approaches to modelling, simulating and predicting behaviour for several reasons:

* Socio-technical systems are simultaneously \emph{very large and heterogeneous}, comprising a a mix of autonomous actors, each with their own behaviours \cite{crabtree00ethnomethodologically}. Systems engineering has traditionally approached the problem of scale through the development of models that abstract complex behaviours and model them as emergent system properties \cite{vespignani11model}. However, these stochastic treatments do not capture the complex interactions that occur between heterogeneous actors, with interactions occurring across different scales of activity. For example, \citet{lock07observations} observed the disruptions caused to a national election in Scotland caused by a variety of small scale technical system defects.
* The behaviour is contingent on unpredictable circumstances, including both factors in the environment and concerning the system actors. For example, the time and manner in which a task, such as developing a new feature for a software system, is completed may vary considerably between actors with different training and experiences. Similarly, the decision to work on a task at all may depend on unpredictable and uncontrollable external circumstances (such as a power outage). In these circumstances, actors may also take it upon themselves to complete tasks outwith expected workflows in order to discharge their responsibilities, by working from a nearby cafe for example, even if this violates organisational security policies. As \citet{besnard03human} note, such adaptations often make the human actors the dependable parts of a socio-technical system.
* Behaviour is continually evolving, as the autonomous actors in a system adapt to new circumstances, discover optimisations to their workflows, adapt the workflow to suit local organisational priorities or take shortcuts \citep{bonen79evolutionary,Lyytinen2008,anderson04heterogeneous}. As a consequence, the *de facto* behaviour exhibited within a system may differ from that envisaged by system architects in idealised workflows. For example, a ward manager in a hospital may delay releasing beds for re-allocation by wider hospital management in the anticipation that these will be required by incoming patients later in the day \citep{dewsbury07responsibility}. This evolution of practice may quickly invalidate expected models of behaviour.

We contend that due to these challenges, modelling socio-technical system behaviours using conventional systems engineering methods will typically either result in a model that is tractable, but lacks the necessary detail of the underlying system to provide informative results; so narrow in scope as to be uninformative about the behaviour of the wider system of interest; or so large and complex as to be intractable for analysis, whether manual or automated. Consequently, the design and construction of systems at this scale is still very much a craft, lacking the methods and tools to support modelling and predictive simulation available in other engineering disciplines.

The research contribution of this paper is to present and evaluate a novel environment, Fuzzi Moss, for simulating complex and contingent behaviour in socio-technical systems which addresses this challenge. In our approach, we provide for a separation of concerns between the model of a problem domain, models of idealised socio-technical actor behaviour and the influence of contingent factors that complicate the actual execution of idealised workflows in practice. The separation of concerns is achieved by modelling:

* The problem domain as collection of classes implemented in the Python programming language.
* Idealised workflows descriptions as executable Python classes in the agent oriented modelling framework, Theatre\\_Ag \citep{theatreag}.
* Contingent behaviour as \emph{dynamic fuzzing aspects} that can alter the flow of execution in workflow descriptions during the execution of a simulation, using the PyDySoFu library \citep{wallis2017pydysofu}.

Both the Theatre\_Ag framework and PyDySoFu libraries were implemented specifically for this work.

Critical to the approach is our hypothesis that:

**Hypothesis: Dynamic fuzzing of workflow descriptions can represent the effect of complex and contingent behaviour by actors in socio-technical systems, when following idealised workflows.**

To test this hypothesis, an example socio-technical case study of team based software development was developed. The case study compares the performance of different software development processes when a software development team follows idealised workflows that have been subject to contingent behaviour. Development processes are compared based on their effect on the emergent properties of the simulated system under development, specifically features implemented and mean time to failure.

The rest of this paper is structured as follows. Section \ref{sec:related} discusses related work, covering existing techniques for modelling socio-technical workflows and other applications of code fuzzing in software engineering. Section \ref{sec:fuzzi-moss} presents the method for constructing models of socio-technical systems, associated workflows and denoting desired fuzzings. Where relevant, this section also discusses details of the implementation details for Fuzzi Moss. Section \ref{sec:evaluation} presents the case study evaluation of the method and Section \ref{sec:conclusions} discusses conclusions and future work, as well as noting the potential for applying fuzzing to other forms of socio-technical models.

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| Figure 1. Modified Research Model |

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| --- | --- | --- |
| Table 1. A Sample Table | | |
|  | Treatment 1 | Treatment 2 |
| Setting A | 125 | 95 |
| Setting B | 85 | 102 |
| Setting C | 98 | 85 |

Table 1. A Very Nice Table

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# References

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