

# Chapter 4

## Multi-Modeling, Meta-Modeling, and Workflow Languages

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### ABSTRACT

*Models, created using different modeling formalisms or techniques, usually serve different purposes and provide unique insights. While each modeling technique might be capable of answering specific questions, complex problems require multiple models interoperating to complement/supplement each other. This Multi-Modeling approach for solving complex problems is full of syntactic and semantic challenges. In this chapter, a systematic methodology for addressing Multi-Modeling problems is presented. The approach is domain specific: domain identification and domain analysis are the first steps in which the multi-modeling concepts and modeling techniques associated with a domain of interest are identified and analyzed. Then a new Domain Specific Multi-Modeling Workflow Language supported with a domain ontology is used to construct the workflow that defines the interoperation of the selected models. The domain ontology provides semantic guidance to affect valid model interoperation. This general approach is illustrated using a case study from the Drug Interdiction and Intelligence application domain. Analysis of diverse intelligence and sensor data using various modeling techniques is essential in identifying the best courses of action. For this example, the created workflow focuses on the interoperation of Social Networks, Timed Influence Nets, and Geospatial Models.*

### INTRODUCTION

The modeling of systems that include humans for the analysis of their behavior in response to external stimuli is an example of a complex problem that requires development and interoperation of a set

of several models. Each model, developed using a different modeling language or formalism, but having access to a common shared data repository, offers unique insights and makes specific assumptions about the system being modeled. Interoperation of such models can produce a

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more robust modeling and simulation capability to support behavior and performance analysis and evaluation.

In order to address the modeling and simulation issues that arise when multiple models are to interoperate, four layers need to be addressed (Figure 1). The Physical one, in which Hardware and Software reside, is a platform that enables the concurrent execution of multiple models expressed in different modeling languages or formalisms and provides the ability to exchange data and also to schedule the events across the different models. The Syntactic layer ascertains that the right data are exchanged among the models. The Physical and Syntactic layers have been addressed by the development of several testbeds that enable model interoperation. Two such examples are the SORASCS test bed (Garlan et al., 2009) and the C2 Wind Tunnel platform (Hemingway et al., 2011). Once this is achieved, a third problem needs to be addressed at the Semantic layer, where the interoperation of different modeling formalisms is examined to ensure that conflicting assumption in different modeling languages are recognized and form constraints to the inter-operation and the exchange of data. Finally, in the Workflow layer, valid combinations of interoperating models are linked to address specific issues. The focus of this chapter is the description of a systematic methodology for creating and implementing Multi-

Modeling Workflows that are both syntactically and semantically correct, i.e., the focus is on the Semantic and Workflow layers.

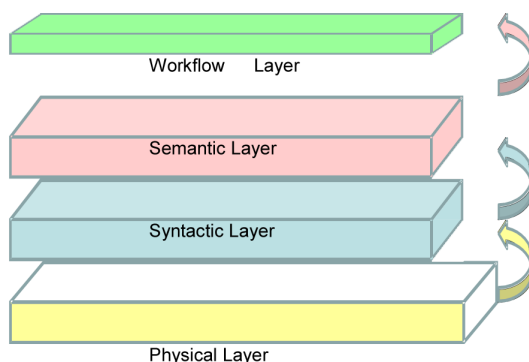
The methodology is illustrated in an application from the Drug Interdiction and Intelligence application domain. The Joint Interagency Task Force - South (JIATF-South), an agency well known for interagency cooperation and intelligence fusion (Munsign and Lamb, 2011), receives large amounts of data from diverse sources regarding drug smuggling efforts. Analysis of such data using various modeling techniques is essential in identifying best Courses of Action. The methodology is applied to the solution of a class of problems in this domain by creating workflows of model interoperations involving Social Networks, Timed Influence Nets, and Geospatial models.

In the background section, a discussion of the basic concepts and approaches is presented. In the following section the key steps in the methodology are described. The domain specific illustrative application is described in the fourth section. Conclusions and discussion of future work are in the final section.

## BACKGROUND

The idea of using a variety of modeling formalisms to solve a complex modeling and analysis problem is not a new one: an earlier survey and a collection of papers on the use of multiple *strategies* for machine learning problems can be found in (Michalski and Tecuci, 1994). Some examples of more recent work employing multi-modeling are: the integration of First-order Logic with Bayesian probability theory in the form of an approach called MEBN (Carvalho et al., 2008), Interoperable Technosocial Modeling (ITM) which focuses on the integration and evaluation of human and physical models across diverging modeling platforms, e.g., Bayesian Nets and System Dynamics (Whitney and Walsh, 2010), and

*Figure 1. The four layers of multi-modeling*



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