Managing Dynamic Contexts Using Failure-Driven Stochastic Models

Nikita A. Sakhanenko and **George F. Luger**
Dept. of Computer Science, Univ. of New Mexico
Albuquerque, New Mexico

Carl R. Stern
Management Sciences, Inc.
Albuquerque, New Mexico

Abstract

We describe an architecture for representing and managing context shifts that supports dynamic data interpretation. This architecture utilizes two layers of learning and three layers of control for adapting and evolving new stochastic models to accurately represent changing and evolving situations. At the core of this architecture is a form of probabilistic logic used to encode sets of recursive relationships defining Dynamic Bayesian Models. This logic is extended with a syntax for defining contextual restrictions on stochastic Horn clauses. EM parameter learning is used to calibrate models as well as to assess the quality of fit between the model and the data. *Model failure*, detected as a poor fit between model and data, triggers a model repair mechanism based on causally informed context splitting and context merging. An implementation of this architecture for distributed weather monitoring is currently under development.

Introduction

Understanding and characterizing context is critical for real-time diagnostic and prognostic reasoning. Context can mediate the interpretation of highly complex data by activating a specific set of inferential strategies and focal points, such as the temporary focus on the causal role of a particular component or subsystem state. The use of inferential strategies and selective focus can serve to reduce the computational size of an estimation task in a probabilistic model by mitigating the need to continuously link local estimation tasks to probability updating over the entire world model.

Modeling context also demands the ability to forget less relevant and/or older information and to shift attention to significant aspects of the current data. Moreover, while modeling a dramatically changing world, transforming context across time can reflect deep changes in the complex internal structure of the world model. Our probabilistic modeling environment supports these and other aspects of context revision.

Many current probabilistic modeling systems, especially those that rest on a knowledge-based model construction approach (Wellman, Breese, & Goldman 1992), map an entire knowledge base into an often complex graphical model. As the size of the resulting network grows large, it becomes time consuming and cumbersome to manipulate, and the inference algorithm can take an exponentially longer time to finish probability updating. Thus, a primary reason for representing contexts dynamically is to reduce the complexity of the constructed model and, consequently, to streamline the inference process. Representing an evolving context requires omitting information that is no longer relevant to the current task from a knowledge base, and at the same time constructing and maintaining the graphical model of the context.

A final reason for creating dynamic contexts in probabilistic modeling systems is the ability to combine multiple *snapshot* models – those models that represent stationary or smoothly evolving stochastic processes. We can think of a single context as a snapshot model; when the context evolves, the modeling system integrates aspects of other snapshot views of the domain. This can be very useful for representing non-stationary processes with abrupt changes. Moreover, our reasoning engine includes failure detection and recovery mechanisms based on causal representations (Pearl 2000). By employing these meta-structures, we can support the explicit characterization and manipulation of context to perform diagnostic and prognostic analysis of complex distributed environments.

In the next section we describe with further detail our dynamic system in which the notion of context plays a major role. Then, after briefly summarizing research related to our approach, we focus on the role of context for reorganizing a current model. We show how context can be used to achieve non-stationary probabilistic modeling with the introduction of contextual mechanisms, such as *context splitting* and *context merging*. We then present the details of our failure-driven dynamic context system through pseudocode, describe the current developmental state of the system, and conclude.

Dynamical Systems Driven by Failure and Recovery Mechanisms

Probabilistic modeling systems that dynamically represent frequently changing data are very important for carrying out complex tasks. Complex modeling systems that can employ available domain knowledge to increase computational efficiency are of the greatest interest. With the increasing use

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Table of Contents Managing Dynamic Contexts Using Failure Driven Stochastic

1. Understanding the eBook Managing Dynamic Contexts Using Failure Driven Stochastic
    - The Rise of Digital Reading Managing Dynamic Contexts Using Failure Driven Stochastic
    - Advantages of eBooks Over Traditional Books
2. Identifying Managing Dynamic Contexts Using Failure Driven Stochastic
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Managing Dynamic Contexts Using Failure Driven Stochastic
    - User-Friendly Interface
4. Exploring eBook Recommendations from Managing Dynamic Contexts Using Failure Driven Stochastic
    - Personalized Recommendations
    - Managing Dynamic Contexts Using Failure Driven Stochastic User Reviews and Ratings
    - Managing Dynamic Contexts Using Failure Driven Stochastic and Bestseller Lists
5. Accessing Managing Dynamic Contexts Using Failure Driven Stochastic Free and Paid eBooks
    - Managing Dynamic Contexts Using Failure Driven Stochastic Public Domain eBooks
    - Managing Dynamic Contexts Using Failure Driven Stochastic eBook Subscription Services

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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