Chapter 4
Complex Event Processing in Sensor–Based Decision Support Systems

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ABSTRACT

Sensor-based decision support systems have to cope with a high volume of continuously generated sensor events. Conventional software architectures do not explicitly target the efficient processing of continuous event streams. Due to the high volume of events and their complex dependencies it is not possible to have a fixed or predefined process flow on the business level. Recently, Complex Event Processing (CEP) has been proposed as a general process model for event streams. Though CEP provides mechanisms for computing high volume of events, it does not define any methodologies, models and reference architectures, which would establish EDA as a mature software architecture. In this chapter the authors present a reference architecture for sensor-based decision support systems, which enables the analysis and processing of complex event streams in real-time. The proposed architecture provides a conceptual basis for development of flexible software frameworks that can be adapted to meet various applications needs. The authors’ architectural approach is based on semantically rich event models providing the different stages of the decision process. They illustrate their approach in the domain of road traffic management for high-capacity road networks.

INTRODUCTION

Decision Support Systems (DSS) are information systems that provide assistance to humans involved in complex decision-making processes. The fundamental task for modern DSS is to help decision-makers in building up and exploring the implications of their judgements (French, 2000).
Nowadays, many decision support systems are based on spatially distributed sensors. Sensor systems have established themselves in many applications and systems with varying characteristics (Estrin et al., 2001). Possible application domains are extremely manifold, e.g. wildlife observation (Mainwaring et al., 2002; Juang et al., 2002), glacier and ocean monitoring (Martinez et al., 2004; ARGO, 2009), monitoring vital signs of patients (Baldus et al., 2004), vehicle tracking (Palms, 2009), laboratory management (Dunkel & Bruns, 2008) or traffic management (Dunkel et al., 2008). Due to these different application areas the technical architectures of these systems differ widely as described in some more details in (Römer & Mattern, 2004). Generally, sensor networks are characterized by producing a high volume of fine-grained data, which is emitted by the sensors. Sensor-based decision support systems must deal with continuously arriving event streams (Luckham, 2002; Babu & Widom, 2001). Due to the high volume of events and their complex dependencies, no predefined workflow can be specified. A key issue of sensor networks is how to process sensor data streams and trigger appropriate business actions in downstream backend systems.

Current software architectures do not target event-based systems, because they are based on a process-oriented control flow, which is not sufficient for event-driven systems. In recent years, Event-Driven Architecture (EDA) has been proposed as a new general processing model for event streams (Luckham, 2002). The key concept is to use Complex Event Processing (CEP) as process model for event-driven decision support. Event streams emitted by sensors contain a high volume of different events, which must be transformed, classified, aggregated and evaluated to initiate appropriate domain actions.

Though CEP provides mechanisms for computing high volume of events, it does not define any methodologies, models and standards, which would establish EDA as a mature software architecture. Thus, one of the main issues is, identifying the general architectural components of an Event-Driven Architecture and to show, how CEP approaches can be integrated into enterprise applications. In particular, the main building blocks of EDA are strongly depending on the application domain.

In this chapter, we propose a general software architecture for sensor-based decision support systems based on Event-Driven Architecture and Complex Event Processing concepts. Our reference architecture enables the analysis and processing of complex event streams in real-time and is therefore well-suited for decision support in sensor-based systems. The proposed architecture provides a conceptual basis for development of flexible software frameworks that can be adapted to meet various applications needs. Our architectural approach is based on semantically rich event models providing the different stages of the decision process.

The remainder of the chapter is organized as follows. In the next section, the main concepts of Event-Driven Architecture and Complex Event Processing are introduced and the building blocks of EDA are identified. Subsequently, the state of the art in the area of Event-Driven Architecture and Complex Event Processing is discussed briefly. Afterwards, a reference software architecture for sensor-based decision support systems is derived. The approach is illustrated by means of the design of a traffic control system for managing a high-capacity road network. In the last section, we summarize the most significant features of our approach and provide an outlook on future lines of research.

**FOUNDATIONS OF EVENT-DRIVEN ARCHITECTURE**

Event-Driven Architecture (EDA) provides an architectural concept for dealing with continuous streams of events. In contrast to other approaches
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