**Sleep Detection System for Vehicle Drivers**

**Case Study Analysis**

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# **Abstract**

This report documents the results of applying the Architecture Analysis and Design Language (AADL) in designing and developing a sleep detection system for vehicle drivers. While driving fatigue and microsleep at the wheel are often the cause of serious accidents. However, these initial signs of fatigue can be detected before a critical situation arises. The proposed sleep detection system for drivers can do this by tracking eye movements using sensors like camera and infrared sensors [[1]](#_References).

# **1 Introduction**

This document presents the results of a case study of the application of the Architecture Analysis and Design Language (AADL) to the Sleep Detection System for Vehicle Drivers.

Model-based software design is the application of model-based engineering techniques (i.e., the use of models and abstractions to perform typical engineering tasks) to design, verify and validate software. Model-based software design relies on analytical practices using analysis and modelling languages and supporting tools. AADL is a Society of Automotive Engineers (SAE) standard for predictable model-based engineering of real-time and embedded computer systems which was first released in 2003.[[2]](#_References)

The AADL and its supporting tools such as the Open Source AADL Tool Environment (OSATE) [SEI 2010][[3]](#_References) have been designed to design and capture the architecture of embedded software systems in terms of the application software as a runtime architecture deployed on a computer system. This allows the software architect to develop a thorough understanding of and insight into (1) critical characteristics vital to a system’s correct operation and (2) the impact the runtime architecture and computer system deployment on the non-functional system properties. These characteristics include considerations such as sensor/command data latency and update rates; CPU throughput; synchronous/asynchronous task management; and data-bus packet definitions and update rates. The SAE AADL industry standard for modelling and analysis of embedded software system architectures was chosen because of its ability to support analysis of non-functional properties, such as robustness, safety, performance, and security. An example for AADL model is shown in Figure 1

A close up of a map

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Figure 1:An example of AADL model

The model and analyses presented in this report are results of a case study effort that is applying the AADL to represent and analyse the proposed sleep detection system for vehicle drivers.

The report is organized as follows:

* Section 2 provides an overview of sleep detection system for vehicle drivers.
* Section 3 presents AADL model of sleep detection system for vehicle drivers
* Section 4 provides the architectural analysis of the provided aadl model
* Section 5 provides summary of key insights of this case study

# **2 Overview of** **Sleep Detection System for Vehicle Drivers**

When driving alone on highways or driving over a long period of time, drivers are inclined to feel bored and sleepy or even fall asleep. Feeling sleepy while driving could result in hazardous traffic accident. So, sleep detection for drivers is crucial for safety of the driver and for those on the road. Particularly important for truck drivers who drive for a living and for people who prefer driving as their preferred mode of transportation. Most of the products for driver anti-sleep system sold in the market is a simplistic audio system making intermittent noises which is quite annoying and inefficient. Some of the existing solutions used in automotive industry are:

* Rest recommendation system developed by Audi
* Driver Alert system developed by Ford
* Attention Assist developed by Mercedes-Benz.

But these systems are either costly or their usage is limited by proprietary.

So, the considered system for case study proposes a cheap and efficient Sleep Detection System for Vehicle Drivers which makes use of use of Kinect detector which has camera sensors with real time image processing and Infrared sensors. The data from sensors are used for eye-lid distance tracking algorithm in order to detect sleepiness and trigger a sound alarm along with flashing LED to notify the user. The functional architecture of the system is shown as a system level block diagram in Figure 2

A screenshot of a cell phone

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Figure : Functional Architecture of the system

The Kinect detector is used to monitor the driver by capturing face images and projecting infrared waves. The data from the camera is provided to a day time detection algorithm and data from IR sensor is provided to night time detection algorithm. The system consists of a processor and alarm system consisting of LEDs and audio outputs. The system is powered by external power supply unit.

Few of the salient functional features of the system are listed below:

* Eye feature extraction to determine sleepiness.
* Real time image processing and eye tracking.
* Sound and flashing LED alarm system to draw driver’s attention.
* Minimalistic interference and potential hazard to users driving.
* Portable and compact system with external power supply inlet.

# **3 AADL model Description of Sleep Detection System for Vehicle Drivers**

The AADL model provided for case study is designed using a **Pipeline architecture** and consists of a system named “AntiSleepSystem” with the below subcomponents:

* A Process named “Controller” which has an in-event port and 3 out-vent ports.
* A Processor named “SystemProcessor” with memory sub-component “RAM” and bus access.
* A Device named “KinectDetector” with out-event port and bus access.
* A Device named “AudioSystem” with in-event port and bus access
* A Device named “LEDDisplay” with in-event port and bus access
* A Device named “DomeLights” with in-event port and bus access
* A Bus named “HardwareConnection” which connects all the devices and the processor.

The AADL model of the system is as shown in Figure 3

A screenshot of a cell phone

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Figure AADL Model Architecture

Please refer the appendix which includes the detailed aadl texture model of the system. From the given aadl model it appears that the flow in the system occurs from the flow source device “KinectDetector” whose output is provided as input to the process “Controller”. Based on the input data, the process “Controller” decides to operate the devices “DomeLights”, “AudioSystem”, “LEDDisplay” to provide alarm notification to the vehicle driver.

# **4 Architecture Analysis**

As part of this case study, we performed several analyses supported by AADL as listed below:

* Mass and weight analysis:

Below is the result of the mass analysis done through osate analysis plugin;

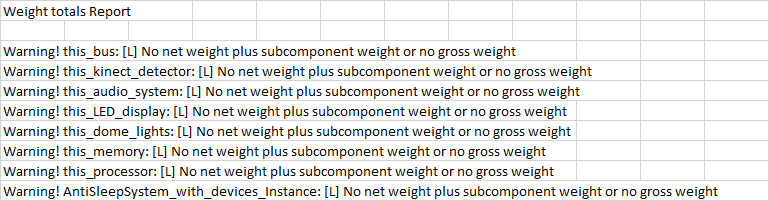
****

Figure Mass and Weight Analysis

Since the software architect of the provided model has not assigned any mass property values to system type or system implementation and its sub-systems, the mass and weight analysis report provided warnings for each of them.

* Power requirements analysis:

The osate plugin failed to perform this analysis since the software architect of the provided model has not assigned any power property values to the system implementation and its sub systems.

* Safety Analysis[[5]](#_References):

During the case study we tried to perform Fault-Tree Analysis(FTA) to get the dependencies between error events and failure modes, and Functional Hazard Analysis(FHA)[[2]](#_References) to get the detailed failure inventory with their description and classification, and Fault-Impact Analysis(FIA) to check error propagations from error source to impacted component but since the model did not have any error propagations or error state transitions, we could not proceed further with them

A screenshot of a cell phone

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Figure Fault-Tree Analysis

* Resource Budget Analysis Report:

A screenshot of a cell phone

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Figure Resource Budgets Analysis

# **5 Summary**

In this case study investigation, we have provided an overview of the proposed sleep detection system for vehicle drivers and explained how AADL is being used to model the proposed system and represent its architecture. We further tried to investigate and analyse the model using AADL plugins in OSATE but due to the insufficient model implementation we were unable to perform them.

# **Appendix**

**AADL textual representation**

A screenshot of text

Description automatically generated

Figure AADL textual model of system

A screenshot of text

Description automatically generated

Figure AADL textual model of system

A screenshot of a cell phone

Description automatically generated

Figure AADL textual model of system

# **References**

[1] - <https://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/driver-assistance-systems/driver-drowsiness-detection/>

[2] - <https://resources.sei.cmu.edu/asset_files/Webinar/2014_018_101_424910.pdf>

[3] - <http://www.aadl.info/aadl/currentsite/>

[4] - <https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=9407>

[5] - <https://people.cs.clemson.edu/~johnmc/courses/cpsc875/resources.html>