Cardiogram: Visual Analytics for Automotive Engineers
Sedlmair, Isenberg, Baur, Mauerer, Pigorsch, Butz
Design Studies
Today’s Design Study

Application Area: Automotive Engineering

Study Environment: With BMW Group
Outline

Problem and Requirement Analysis

Design of Cardiogram

Evaluation of Cardiogram
Problem & Requirements
General Motivation: More and more electronics...
... Enabled by In-car Communication Networks

Controllers

Gateway
General Problem: It got complex...

~100 Controllers

15,000 messages / sec

General Challenge: Understand Network Data
Methodology

Studies with and without tools

~150 Engineers / 3.5 years

Grounded Theory
Our Focus Today

**Target Users:** In-car Network Analysts

**Task:** Find errors in in-car communication networks

**Procedure:** Test drives and data analysis
Data: Recorded Traces (List of network messages)

A usual trace (15 minutes): ~10 million msg.

~100 traces / error case
Current Practices

- Lists of traces
- Simple signal plots
(Some) Problems

Distributed errors?

Car Behaviour vs. Trace?
An Example Problem

Overpressure Sensor Problem

Took Engineers ~4 Month

Reason: All 4 doors slammed simultaneously
Deriving Requirements

- **Handling the masses of data**
  - Data abstraction and automated filtering
  - Support for automated error detection
  - Avoid repetitive work and unnecessary iterations

- **New Perspectives on Complex Errors**
  - Beyond raw data and signal plots
  - Visual Overview Techniques
  - Multiple, modular and coordinated solutions

- **Engineer-centered solutions**
  - Fast access to raw data
  - Familiarity
  - Support collaboration
Requirements: Today’s Focus

- Handling the masses of data
  - Data abstraction and automated filtering
  - Support for automated error detection
- Avoid repetitive tasks and unnecessary iterations
- New Perspectives on Complex Errors
  - Beyond raw data and signal plots
  - Visual Overview Techniques
  - Multiple, modular and coordinated solutions
- Engineer-centered solutions
  - Fast access to raw data
  - Familiarity
  - Support collaboration
Our Solution:
Cardiogram
Our idea: Using State Machines

- Handling the masses of data
  - Data abstraction and automated filtering
  - Support for automated error detection
  - Avoid repetitive work and unnecessary iterations

- New Perspectives on Complex Errors
  - Beyond raw data and signal plots

Visual Overview Techniques

Multiple, modular and coordinated solutions

Engine-centered solutions

Trace

State Machine Engine

Abstract
Detect Errors
Data Reduction
Abstraction: SMs to Interpret Vehicle Behavior (simplified)
Abstraction: SMs to Interpret Vehicle Behavior (simplified)

Door open

Door closed

Interpret Trace
Aut. Error Detection: SMs to Interpret Errors (simplified)

Correct → Error
Data Reduction

- 1 Verification Tag per SM
- 10M messages --> 10K transitions
Visualization

... only when necessary
Visualization
a: State Machine List
b: State Machine Transition View

x-axis: time

y-axis: states
c: Overview Timeline
Evaluation
(Some) Results: State Machine Approach

Externalization of Expert Knowledge

Additional Benefit: Supports Collaboration

Database
(Some) Results: State Machine Approach

Complete Coverage vs. Sparse Samples

Thousands vs. Tens of Traces / Day
(Some) Results: Visualization

Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem

Overpressure error
ok
Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem

(Some) Results: Visualization

- Door 1 closed
- Door 2 closed
- Door 3 closed
- Door 4 closed

Overpressure error
ok
(Some) Results: Visualization

Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem

Overpressure error
ok
Door 1 closed
open
Door 2 closed
open
Door 3 closed
Door 4 closed
open

Create State Machine from Insights

State Machine Creation and Verification
Summary
Cardiogram / Contributions

Based on in-depth domain analysis

A: State Machine Approach

B: Visualization Component

Cardiogram adopted by engineers
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Questions?

Thank you!

Cardiogram: 4 Steps

Core Components

- Editor
- State machine database
- State Machine Engine
- Cardiogram Visualization

Trace