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

Diagram showing in-car communication networks with controllers and a gateway.
General Problem: It got complex...

~100 Controllers

15,000 messages / sec

General Challenge: Understand Network Data
Studies with and without tools

~150 Engineers / 3.5 years

Methodology

Tools for In-Car Network Analysis

Cardiogram

Tools for Other Use Cases

VisTra

AutobahnVis

AutobahnVis 2.0

Cardiogram

ProgSpy2010

MostVis

WiKeVis

RelEx

Car-x-ray

2007

2008

2009

2010
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 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*
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

![State Machine Diagram]

- Trace
- State Machine Engine
  - Abstract
  - Detect Errors
  - Data Reduction
Abstraction: SMs to Interpret Vehicle Behavior (simplified)

Door open ↔ Door closed
Abstraction: SMs to Interpret Vehicle Behavior (simplified)

Door open

Door closed

Interpret Trace

Door closed

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

Correct \[ \rightarrow \] 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

a
c: Overview Timeline
Evaluation
Field Studies during and after deployment

2009

Cardiogram Project

Field study (15 engrs. / ~1 year)

SM

Field study (2 engrs. / 8 weeks)

Vis

Think aloud study (6 engrs. / 1 hour each)

2010
(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

- Overpressure error
  - ok

- Door 1 closed
  - open

- Door 2 closed
  - open

- Door 3 closed
  - open

- Door 4 closed
  - open
Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem

Overpressure error
ok

Door 2 closed
Door 3 closed
Door 4 closed

Create State Machine from Insights

State Machine Creation and Verification

(Some) Results: Visualization
Summary
Cardiogram / Contributions

Based on in-depth domain analysis

A: State Machine Approach

B: Visualization Component

Cardiogram adopted by engineers
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Thank you!
Questions?

Back Up
Cardiogram: 4 Steps

Core Components

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

Trace