Integrated Diagnosis for Future Mobile Systems

Technology Overview and Concepts

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Abstract

This paper describes new hardware and software diagnosis concepts for OnBoard use in mobile vehicles. Following a review of existing diagnostic methodologies, we discuss approaches to the development of next generation model-based diagnosis tool environments which 1) automate the production of diagnosis models from design models, and 2) can improve the diagnostic modeling process flow from design through to in-field service and maintenance. Examples of a model-based reasoning approach to mechanical (powertrain) and electronic (electrical vehicle network) component diagnostics will be shown.

Introduction

Global car and truck manufacturers are substituting increasing numbers of microprocessor-controlled mechatronic systems and components for purely mechanical devices in an effort to achieve improved control and performance at reduced cost [Bäk962]. This trend requires the adoption of new integrated-vehicle and component-specific design and diagnostic modeling methods that scale well with increases in the structural, functional and configuration complexity of mechatronic command/control systems (e.g. powertrains, suspension systems, and "X-by-wire" systems), and of new in-vehicle high speed data/control networks. At the organization level, product design, manufacturing and diagnostics service teams need new approaches to collaboration, communications and learning which support common knowledge representations and concurrent planning, engineering and test across the full vehicle life cycle (see figure 1: introduction slide).

Motivation

Efficient diagnosis of mobile vehicle systems faces substantial constraints in the future:

- The use of a special OffBoard service infrastructure (see figure 2) which integrates links to global service and customer assistance networks and centers, requirements for availability, and the installation of workshops with PC-based diagnosis and centralized database access;
- The shift to an OnBoard network infrastructure (see figure 3), comprising field bus lacing [Bäk973] of control systems and internal networks, new diagnosis-suitable Smart Power sensor technology elements, and the use of powerful micro processors;
- Design and implementation of new AI diagnosis algorithms (see figure 4-7), including model-based diagnosis strategies, enhanced process chain integration – from the creation of diagnosis data to the development of diagnosis systems, the use of overriding software concepts, and the definition of interfaces for decentralized diagnosis modeling;
- Optimization of the diagnostic modeling process chain (see figure 8-9), including automation of the diagnosis data generation process, the diagnosis algorithm and the needed structure data to diagnose components and functions, development of modified software tools environments by vehicle suppliers and manufacturers, improved data handling, and the use and cataloging of mechatronic data models;
- Requirements to integrate new system functions with product value creation (see figure 11), such as new safety- and driver assistance-functions, and remote diagnosis- and maintenance-functions [Bäk981].

These system limitations strongly motivate the development of integrated, system-wide approaches to vehicle OnBoard and OffBoard diagnosis.

Goals and Benefits

The fundamental goals and advantages of a system wide vehicle diagnosis are:

- Control of networked electric/electronic units in the vehicle.
- Enhanced diagnosability of system components.

- Improved passenger safety and vehicle availability (up-time).

Mathematics and Physics Background

The core integrated OnBoard diagnosis systems (see figure 4) utilize complex diagnosis algorithms based on new artificial intelligence (AI) processes under development. These algorithms require knowledge of the underlying technical system structure (e.g.dependencies between the internal system values and the system functions). In principal, qualitative and quantitative diagnosis strategies will be employed (see figure 5-7) as these procedures portray different attributes and views of the target system, making their application conditional on the unit which is monitored.

Automated Data Generation for Component-Specific Diagnosis Model Fragments

The development of new diagnosis procedures also has a large impact on the software tool environment employed during system design through to production (see figure 8-9). Complex electronic structures are today diagnosable only manually. Consequently powerful strategies are necessary to generate automatically parts of the needed diagnosis routines from the available design data.

System Diagnosis - Outlook

An demonstration implementation of a „System Diagnosis“ illustrates the possibility of future diagnosis solutions [For981] for mobile vehicles (see figure 10). With the help of product-integrated diagnostic processes, internal electric/electronic infrastructure and function-component hierarchy information can be employed as a basis for the generation of models for localize faults and fault type, failure causes, and functions which interfere with user operation. A subsequent degree of severity further enables the specification of the procedure instructions.

As the number of mechatronic system components in the vehicles of the future continually increases, new diagnosis concepts and technologies of maintenance and surveillance of these units will be important as well (see figure 11-12). These mechatronic units include passenger compartment and other interior electric/electronic components, Powertrain electromechanical components, "X-by-wire" technology for brake-, control- and damping systems, and new forms of telecommunication systems.

Conclusions

The application of Onboard model-based diagnosis systems in future mobile systems demonstrates numerous advantages over conventional diagnostic approaches. In addition to optimizing the process chain with an integrated tool environment, improvements can also be achieved in the specification of fault information and diagnosis deep models [Bäk982]. Together with new forms of diagnostic infrastructure in customer service and Offboard vehicle services, customer acceptance and the vehicle availability can be improved.

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Book with Multiple Authors

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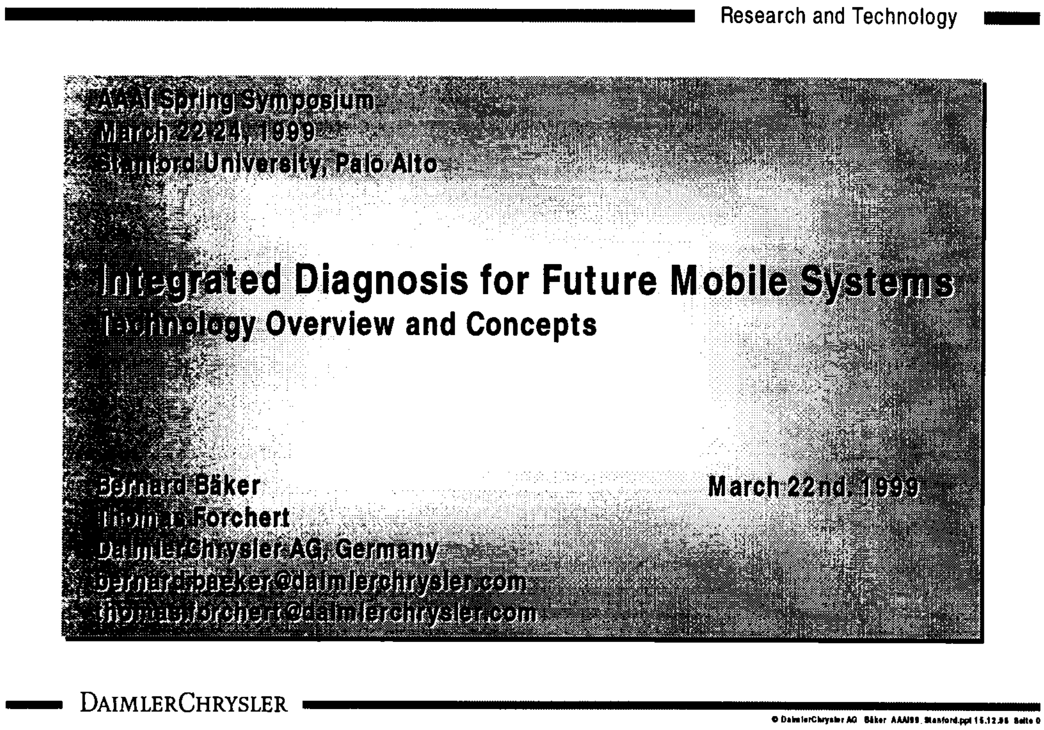

Figure 1: Introduction Slide.

1. Introduction / Motivation

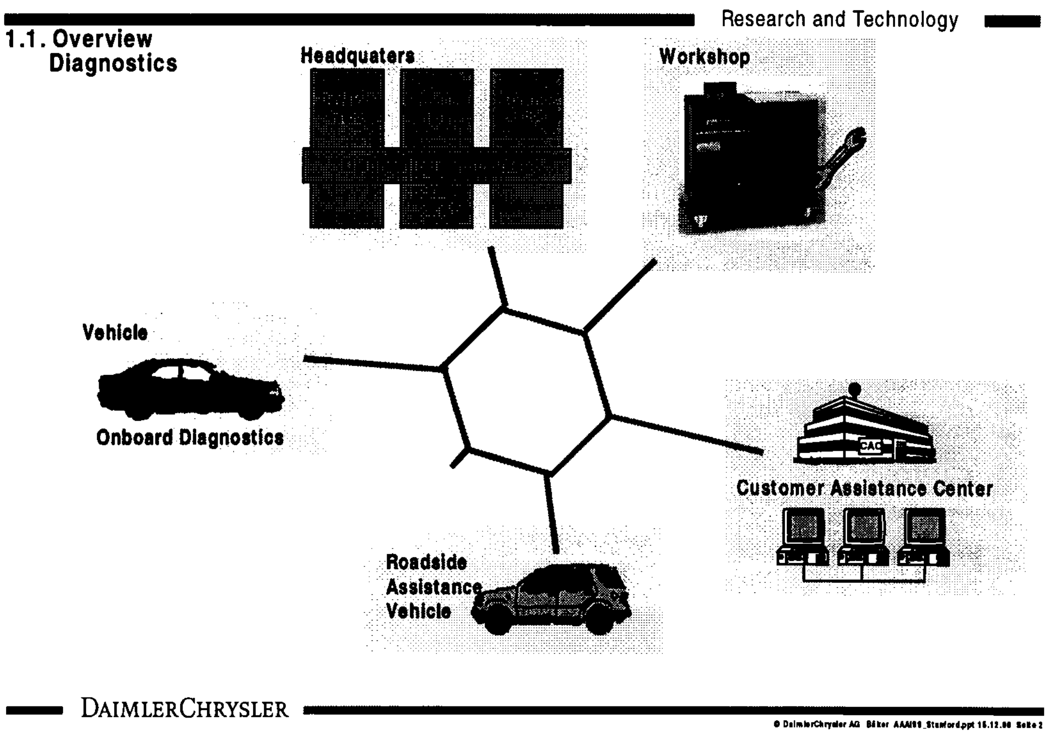

Figure 2: Diagnostics / Overview.

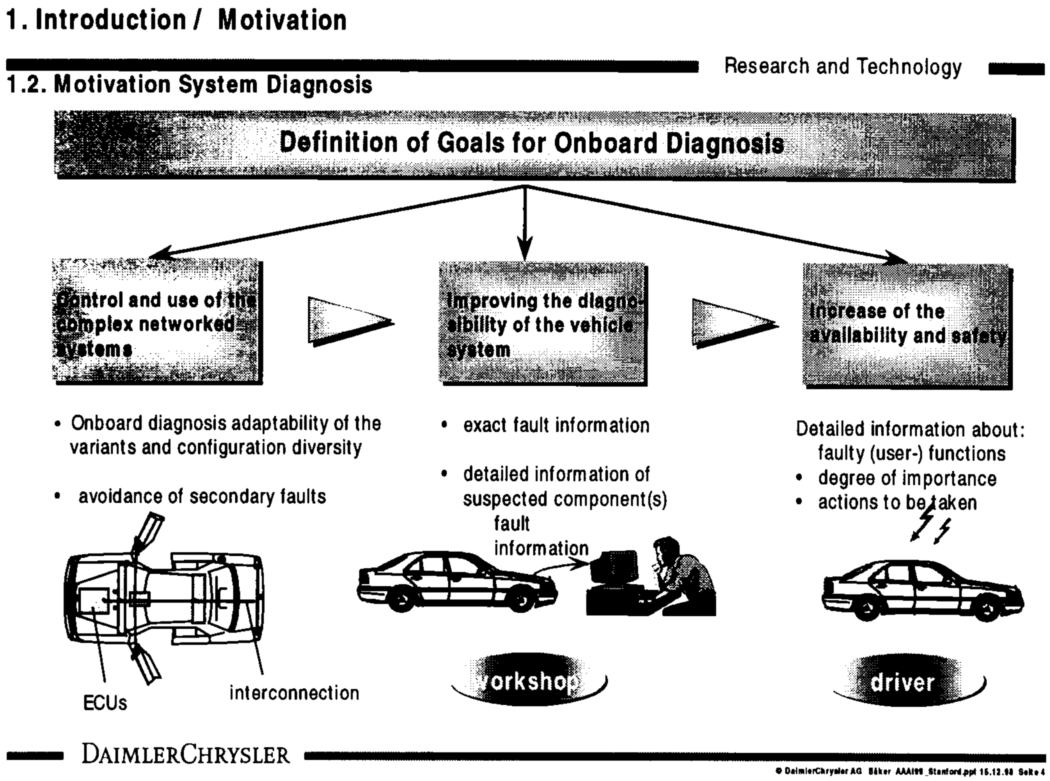

Figure 3: Motivation / Goals of a System Diagnosis.

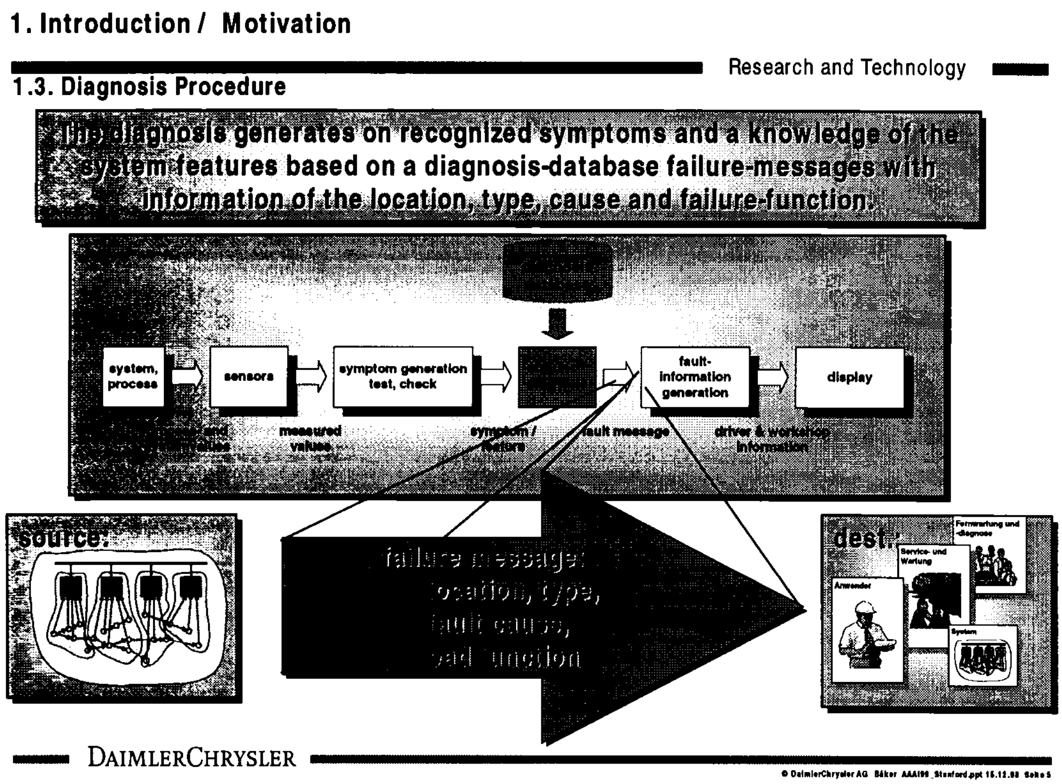

Figure 4: Description of the Diagnosis Procedure.

2. Overview selected diagnosis methods (I)

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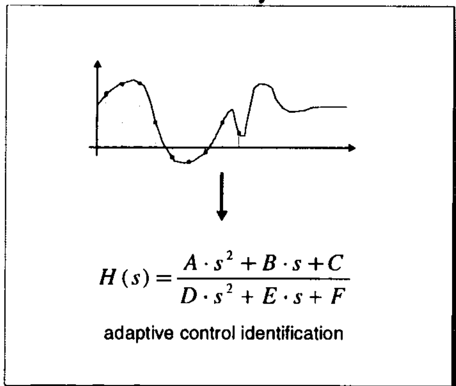
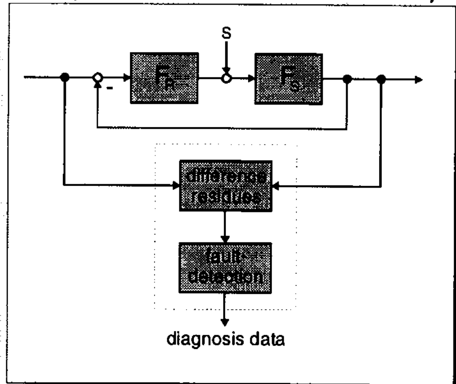
Prof. Isermann
Technical University of Darmstadt



- powerful CPU necessary
+ dynamic process description possible
- complex algorithms used
- no complete process chain
- no multi-fault detection

FDI (Fault Detection and Isolation)



+ compact and quick algorithms
+ dynamic process description possible
o optimization of the process chain
- no multi-fault detection

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Figure 5: Description of Selected Diagnosis Methods I.

2. Overview selected diagnosis methods (II)

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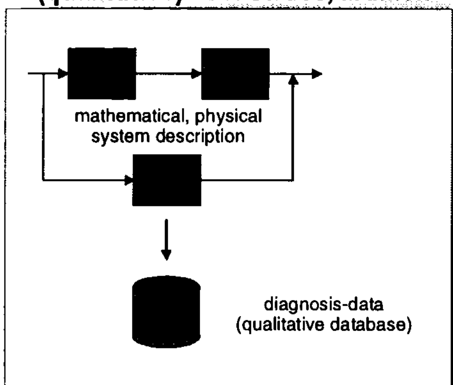
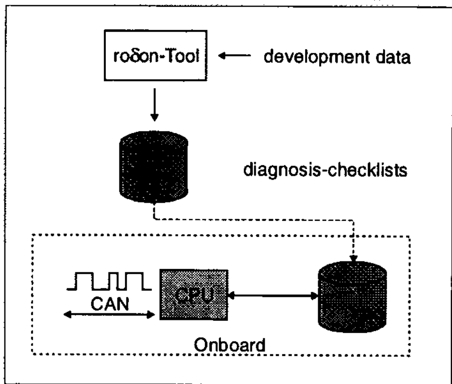
Model-based Diagnosis
(qualitative) - Dr. Struss, Munich



+ no fault-simulation necessary
o dynamic process description possible
+ function- and component-hierarchy
+ multi-faults detection
+ severity of faults
+ structure information of source system
o optimization of the process chain

Model-based Diagnosis
(quantitative) with rodon-Tool



o function- and component-hierarchy
o severity of faults
- no dynamic process description possible
+ optimization of the process chain
o structure information of the source system
- fault-simulation necessary
- no multi-fault detection

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Figure 6: Description of Selected Diagnosis Methods II.

2. Overview selected diagnosis methods (III)

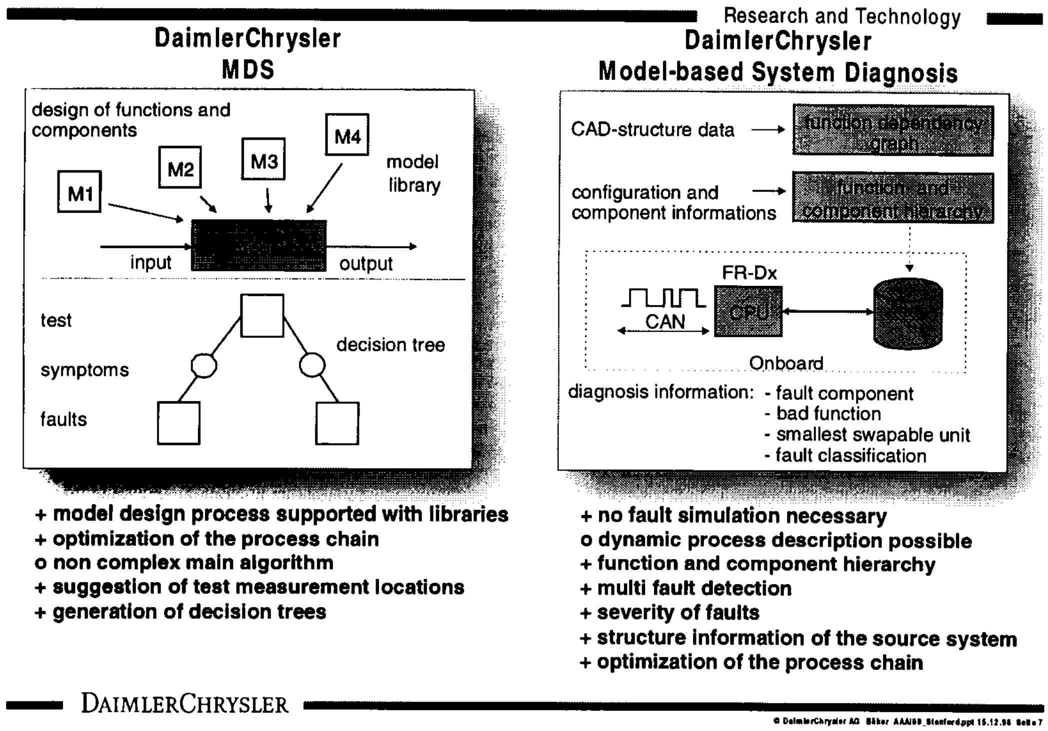

Figure 7: Description of Selected Diagnosis Methods III.

3. Process Chain

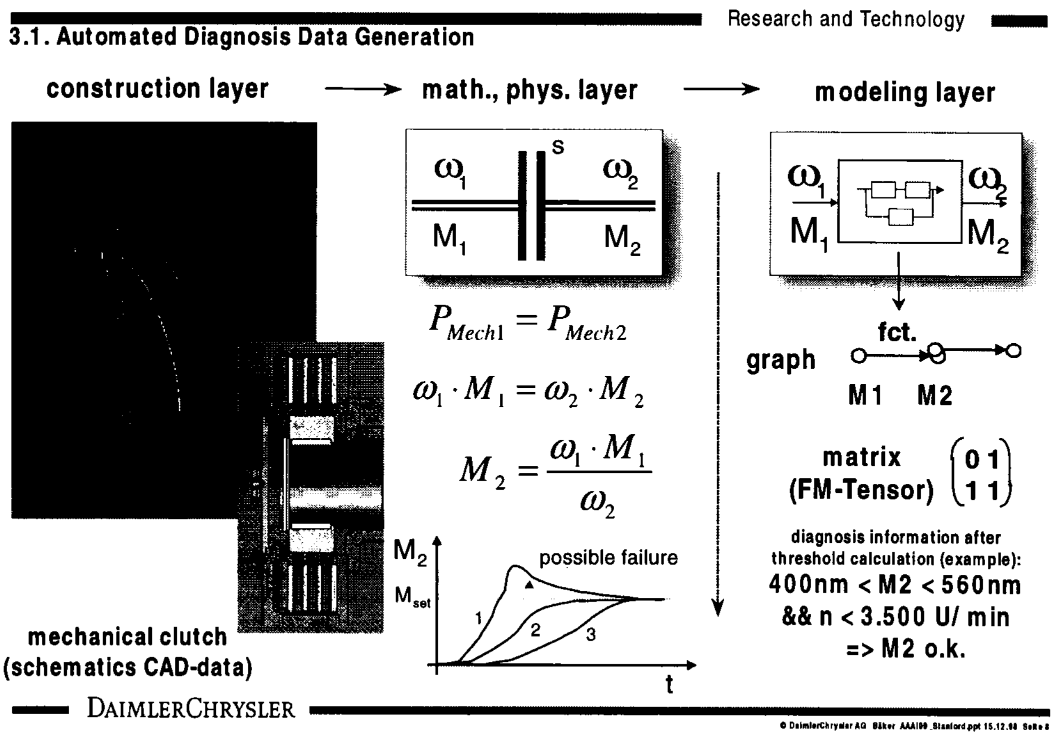

Figure 8: Automated Diagnosis Data Generation Process.

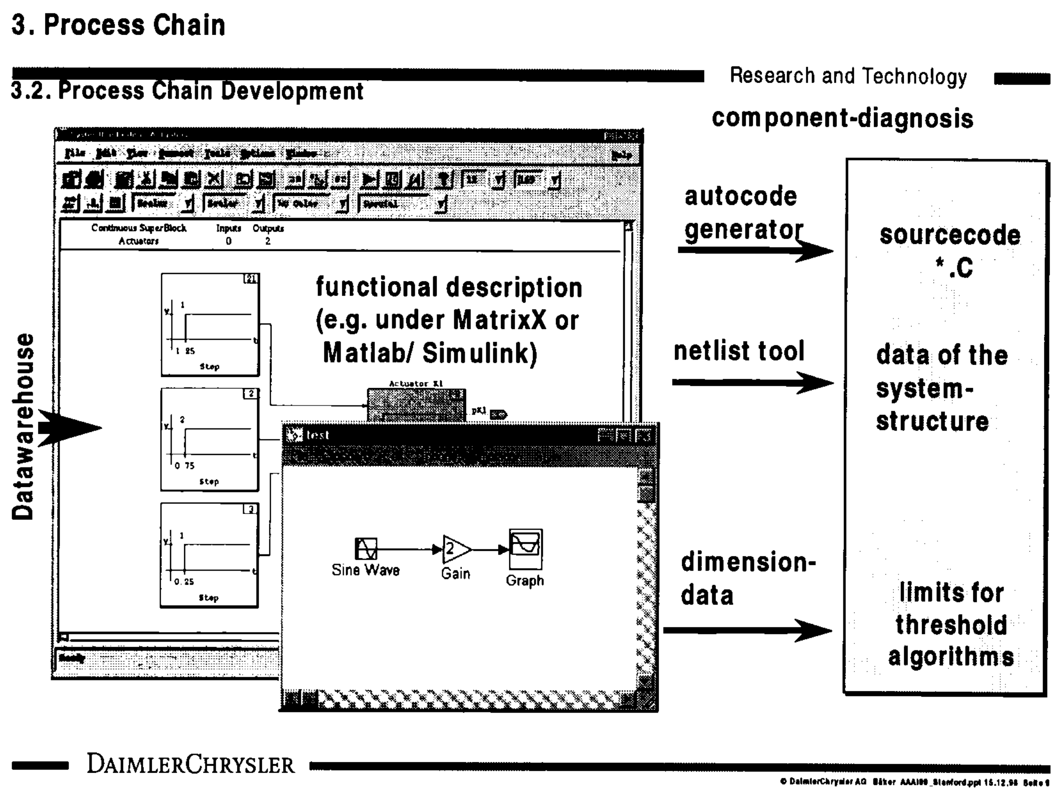

Figure 9: Process Chain Development.

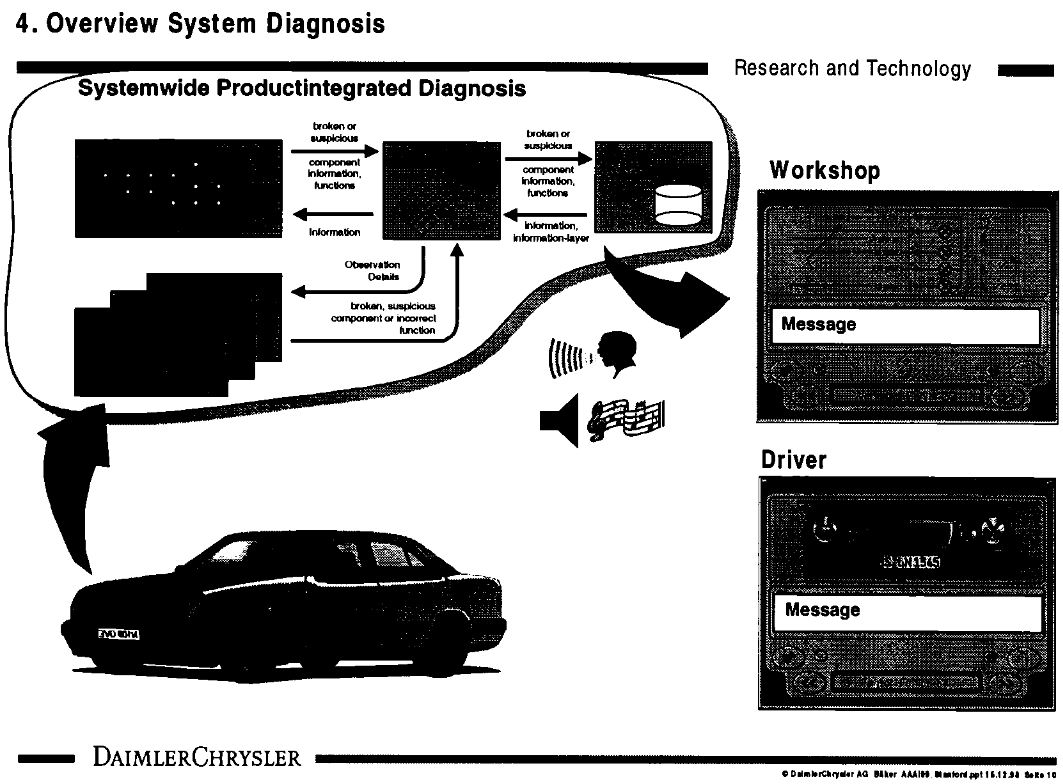

Figure 10: Overview System Diagnosis.

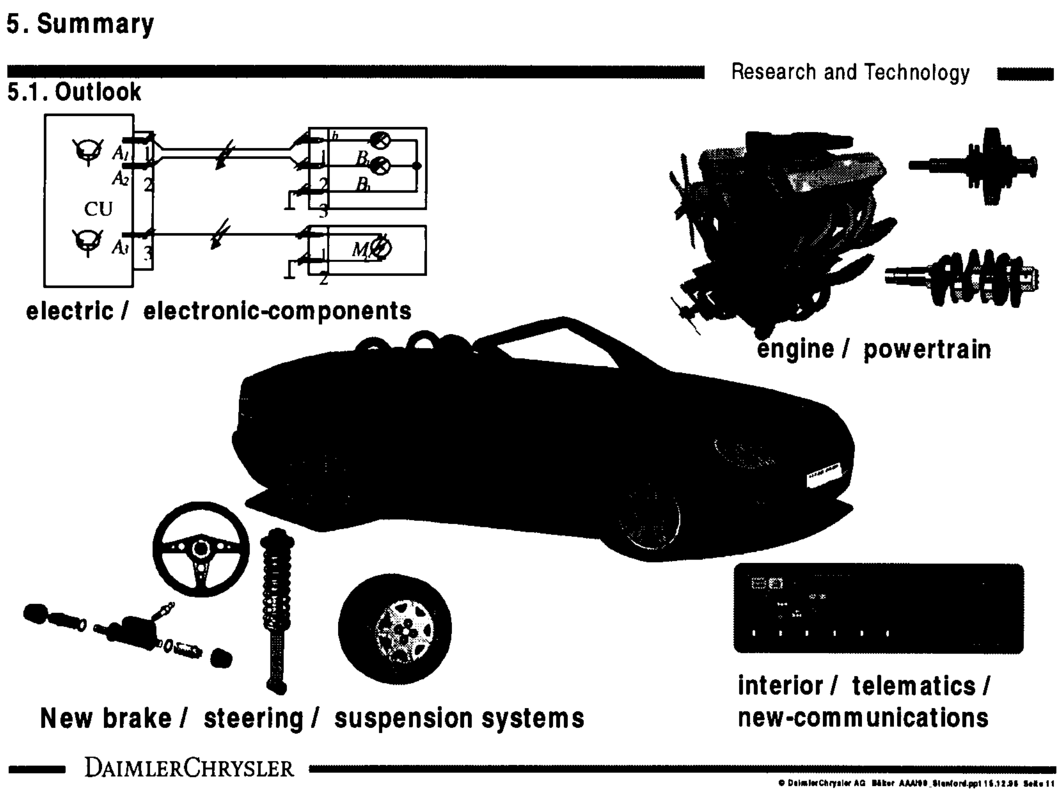

Figure 11: Summary / Outlook.

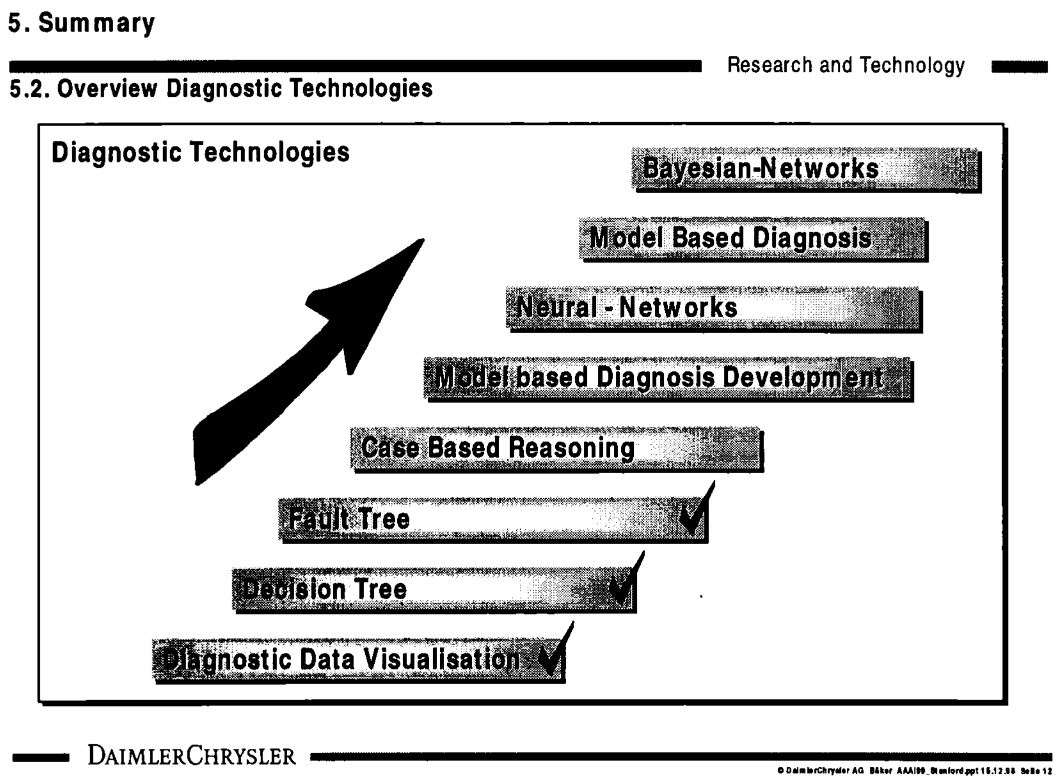

Figure 12: Overview Diagnostic Technologies.