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Remote Diagnosis of Technical Systems

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1 Structure of Remote Diagnosis

Modern technological systems are subject to faults, which may lead to down time and damage to men and environment. The aim of fault diagnosis is to detect and to identify these faults as early as possible.

Diagnostic tasks require considerable computing effort and memory capacity [2]. Remote diagnosis, which decomposes the overall diagnostic problem into on-board and off-board diagnostic problems, reduces the on-board requirements using additional computational resources of remote systems. The structure of remote diagnosis is shown by means of an automotive example in Fig. 1.

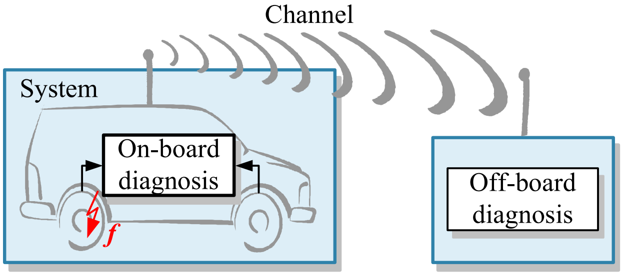

Figure 1: Structure of remote diagnosis

Due to the limited computing resources, complex diagnostic tasks cannot be solved on-board in practice. Modern data communication networks provide the technological basis for the communication between on-board systems and remote systems. Therefore, a communication connection between the on-board systems and the remote systems is arranged to utilise additional off-board computing and memory resources for diagnosis.

Restrictions apply on both sides of the channel. While all measured signals are available on-board, on-board diagnosis has to cope with limited memory and computing resources. In contrast practically unlimited computing power and memory capacity are available on the remote system, but off-board diagnosis works with restricted information affected by limitations of the data communication network. The main limitations concern

- limited bandwidth,
- data loss,
- transportation delay [3].

Due to the limited bandwidth as few as possible data have to be transmitted to the off-board system to sufficiently isolate and identify the faults. Taking these restrictions into account, an appropriate decomposition of the diagnostic task has to be chosen.

2 Decomposition of Diagnosis

The overall diagnostic process usually consists of three steps [1].

1. **Fault detection:** Decide whether or not a fault has occurred.
2. **Fault isolation:** Specify the faulty components.
3. **Fault identification:** Identify the fault and estimate its magnitude.

Each diagnostic steps necessitates models of different complexity. The model complexity and thus the computing effort and memory requirements increase from fault detection towards fault identification.

Considering these restrictions the following decomposition of diagnosis is used in the project.

- **On-board fault detection.** The on-board diagnostic system solves the fault detection problem. Since the detection only needs the model of the nominal system, the solution of this task requires less computational resources.
- **Off-board fault isolation and identification.** The fault isolation and fault identification is solved by the off-board diagnostic system. The fault isolation requires a component-oriented model whereas the fault identification needs behavioural models of the faulty system.

Moreover, the on-board system controls the data traffic from the on-board system towards the off-board system. To solve this task a detection model, whose consistency with the measured system behaviour ensures the faultlessness of the system to be diagnosed, is required [4]. As it is not reasonable to transmit data from the on-board component to the off-board component if it is certain that the system is faultless, the data transmission only takes place if the detection model is inconsistent with the measured system behaviour and, hence, the off-board system can find some fault. The decomposition of the diagnostic tasks is shown in Fig. 2.

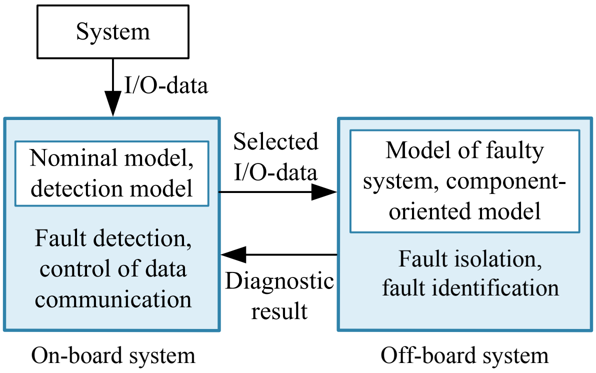

Figure 2: Decomposition of the diagnostic tasks

This concept of remote diagnosis mainly reduces the computational requirements on the on-board component with respect to memory and computing effort. Furthermore, it is ensured that the off-board diagnosis starts early enough to isolate and identify the fault in the shortest time, but data are not transmitted if it is guaranteed that the system is faultless.

3 Timed automata

The diagnostic approach applied in this project models the system by timed automata

$$\mathcal{A}_{\mathrm{T}} = (\mathcal{N}_{\mathrm{z}}, \mathcal{N}_{\mathrm{w}}, \mathcal{N}_{\mathrm{v}}, L_{\mathrm{T}}),$$

where $\mathcal{N}_{\mathrm{z}}$ represents the set of states, $\mathcal{N}_{\mathrm{w}}$ the set of outputs and $\mathcal{N}_{\mathrm{v}}$ the set of inputs. The temporal transition relation

$$L_{\mathrm{T}} : \mathcal{N}_z \times \mathcal{N}_w \times \mathcal{N}_z \times \mathcal{N}_v \times \mathbb{R}_0^+ \longrightarrow \{0,1\}$$

is fulfilled ($L_{\mathrm{T}}(z_{k+1}, w_k, z_k, v_k, \tau_k) = 1$) if for the input v_k the automaton can change its state from z_k towards the successor state z_{k+1} after the sojourn time $\tau_k = t_{k+1} - t_k$ in z_k and thereby generates the output w_k. If the time of a state transition cannot be exactly determined, the sojourn time can be specified by an interval

$$T_{z_{k+1},z_k} = [\tau_{\min}(z_{k+1}, w_k, z_k, v_k), \tau_{\max}(z_{k+1}, w_k, z_k, v_k)].$$

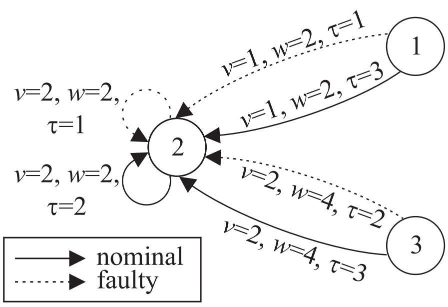

Figure 3: Graph of a timed I/O-automaton

The representation of a timed I/O-automaton by means of an automaton graph is depicted in Fig. 3, where nodes represent the states of the system and each arc between two nodes represents a possible transition from one state to another. The automaton graph describes the nominal behaviour (solid arcs) and the behaviour of the faulty system (dashed arcs). Obviously the behaviours of the faultless and faulty system differ in the corresponding sojourn times. Therefore, a consistency-based diagnostic method can be applied to detect and identify the fault [5].

4 Data communication network

Due to the utilisation of remote resources the limitations of the data communication network have to be taken into account by the off-board diagnosis. In this project two different approaches are investigated both of which use models $\mathcal{A}_{\mathrm{T,N}}$ of the communication network.

In the first approach a serial composition of the model $\mathcal{A}_{\mathrm{T,S}}$ of the system and the model $\mathcal{A}_{\mathrm{T,N}}$ of the network is required (Fig. 4). The benefit of this approach is that the off-board component can utilise models $\tilde{\mathcal{A}}$ describing the system in combination with the network. In the second approach the models $\mathcal{A}_{\mathrm{T,S}}$ and $\mathcal{A}_{\mathrm{T,N}}$ should be separately exploited by the off-board diagnostic algorithms. Consequently, faults, which have occurred in the system, and network faults are distinguishable from each other.

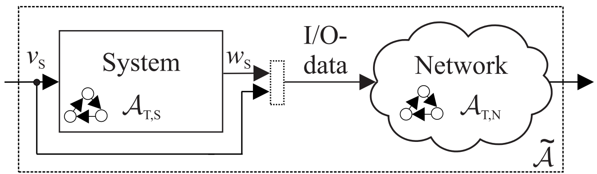

Figure 4: Composition of system and network

5 Support

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