4 Multilayer Attribute-based Conflict-reducing Observation

Based on the motivation given in Section 1.1 and the analysis of the scientific state of the art (cf. Chapter 2), an information fusion system for the determination of a system's current state is proposed in this chapter. This information fusion system is denoted by multilayer attribute-based conflict-reducing observation (MACRO). The concepts presented in Chapter 3 serve as the basis for the research elaborated in this chapter. The research is carried out amongst the work topics defined in Section 1.1 (cf. also Figure 1.3), which fill the scientific gap identified in Section 2.4. MACRO's properties are listed in the following:

- The MACRO system utilises a two-layer fusion system structure to resemble the physical structure of a monitored system. The architecture is defined in the scope of WT 1 and elaborated in Section 4.1.

- The purpose of MACRO is to test the current state of a system and determine the degree, to which it accords with its normal condition. This is based on the sensor signals, which are involved in the information fusion process. These are heterogeneous in type and dimension, and prone to epistemic uncertainty. The information model proposed in Section 4.3 to represent the normal condition facilitates the utilisation of arbitrary sensors and considers epistemic uncertainty as it is based on standard fuzzy sets. It is the result of WT 2. Its parameters are determined automatically from actual measurement data while preserving the possibility of manual adjustments.

- Conflicts between the information from the involved sensors are likely to appear, especially in real-world applications. These conflicts need to be considered during the fusion process. Whereas the information model is embedded in FST, conflict-handling mechanisms are offered by DST. Therefore, an information transfer method is proposed within the research on WT 3 presented in Section 4.4. It is a method transferring fuzzy memberships value-equivalently to basic belief assignments in the sense of DST. Fuzzy memberships are hereby regarded as basic belief assignments to be subsequently processed by fusion methods originating from DST.

- MACRO implements conflict handling in the fusion operation applied on its lower layer. The amount of conflict between the input sensors is determined and handled such that the conflict effects on the fusion result are reduced. The central component of the observation system facilitating said property is the fuzzified
balanced two-layer conflict solving ($\mu$BalTLCS) fusion algorithm, which is based on DST and operates in the framework of FST. It is proposed in Section 4.5 and the result of the research on WT 4.

- The information fusion operation on the top layer creates MACRO’s output, and determines and assesses the current system state. Its inputs are the fusion results of $\mu$BalTLCS on the lower layer. Since all intermediate results are accessible, MACRO represents a transparent fusion system, which allows for the localisation of errors from system level down to the sensors.

Further research considering WTs 5 and 6 follows in the last sections of this chapter. These work topics deal with real-world applications, which benefit from the presented results. A sensor defect detection method based on the monitoring of sensor reliability is proposed in Section 4.7. It assists in the identification of defective sensors in order to increase the trust in a fusion result. Section 4.8 proposes an optimisation of the $\mu$BalTLCS fusion algorithm in the form as it is applied on MACRO’s lower layer. It reduces the algorithm’s computational complexity from quadratic to linear with respect to the number of inputs.

Parts of this chapter have been published in previous contributions. The main contributions are [m.LM10b; m.MPL10; m.MVL12; m.ML13; m.MPL13; m.ML14; m.EML15; m.MTD+15; m.FML16b; m.EML16; m.MDL+16]. The contributions’ textual contents have been transferred literally to this dissertation where suitable.

### 4.1 The MACRO Architecture

Research on the architecture of the MACRO system is carried out in the scope of work topic WT 1: Fusion System Structure (cf. Figure 4.1).

**Figure 4.1:** Location of work topic WT 1: Fusion System Structure inside the information fusion process.

MACRO’s architecture is designed to resemble the actual structure of the monitored system, which is partitioned into several sub-systems on the one hand. This kind of