Fuzzy Modeling and Classification of Human Operator Cognitive Functional State in Human-Machine Systems

One of the challenging problems in designing human-machine cooperative systems is that human operator is either kept 'out of the loop' (if the level of automation is set too high) or vulnerable (prone) to errors even performance breakdown especially under the conditions of high cognitive (or psychological) workload (task-load) and mental stress (strain) (if a human-centered paradigm is used). To cope with this problem, a viable strategy is to use adaptive automation (AA), in which the cognition-demanding tasks are switched dynamically between human and machine (or complex technical systems in general) when high-risk (or vulnerable) human cognitive state (HCS) is detected.

It will be shown in this talk that overall human-machine system performance can be improved and adaptive automation can be achieved by monitoring OFS based solely on multiple physiological and performance markers (features). The main contents of this presentation include: 1) fuzzy models and classifiers were proposed to quantitatively assess the HCS based on the measured physiological and performance data. The fuzzy modelling and clustering techniques are shown to be reliable and relatively robust with respect to the data noise, and thus may be practically applied to a range of individual human operators; and 2) feature selection technique is proposed to reduce the computational burden of the fuzzy data clustering algorithm.

More specifically, a total of 20 sessions of data collection experiments were performed on 10 subjects on a complex and safety-critical process control task platform. A novel 'cyclical loading' experimental scheme is used, in which the cognitive task-load is elevated stepwise until a possible performance breakdown occurs. This scheme enables us to identify the risky human cognitive state (HCS) before performance breakdown occurs. The measured data were then used to construct the fuzzy models and classifiers of the HCS for individual subjects. The risky HCS features, which are most sensitive to the variations in the level of cognitive task-load (intimately related to mental or cognitive stress), were shown to be a few physiological variables including EEG-based task load index and heart rate variability. The customized (or personalized) models (and classifiers) are based on the subject-specific data and their generalization (or prediction) performance is shown to be encouraging. Finally, we will briefly discuss the practical relevance and implications of the fuzzy HCS modeling method developed for implementing the AA of human-machine systems. An essential part of future work will be focused on developing an adaptive control interface aimed at implementing an online closed-loop control system.