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Research Article

Multimodality Inferring of Human Cognitive States Based on Integration of Neuro-Fuzzy Network and Information Fusion Techniques

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To achieve an effective and safe operation on the machine system where the human interacts with the machine mutually, there is a need for the machine to understand the human state, especially cognitive state, when the human's operation task demands an intensive cognitive activity. Due to a well-known fact with the human being, a highly uncertain cognitive state and behavior as well as expressions or cues, the recent trend to infer the human state is to consider multimodality features of the human operator. In this paper, we present a method for multimodality inferring of human cognitive states by integrating neuro-fuzzy network and information fusion techniques. To demonstrate the effectiveness of this method, we take the driver fatigue detection as an example. The proposed method has, in particular, the following new features. First, human expressions are classified into four categories: (i) casual or contextual feature, (ii) contact feature, (iii) contactless feature, and (iv) performance feature. Second, the fuzzy neural network technique, in particular Takagi-Sugeno-Kang (TSK) model, is employed to cope with uncertain behaviors. Third, the sensor fusion technique, in particular ordered weighted aggregation (OWA), is integrated with the TSK model in such a way that cues are taken as inputs to the TSK model, and then the outputs of the TSK are fused by the OWA which gives outputs corresponding to particular cognitive states under interest (e.g., fatigue). We call this method TSK-OWA. Validation of the TSK-OWA, performed in the Northeastern University vehicle drive simulator, has shown that the proposed method is promising to be a general tool for human cognitive state inferring and a special tool for the driver fatigue detection.

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1. INTRODUCTION

Broadly speaking, any machine system involves human-machine interaction, for example, the vehicle system where the driver interacts with the vehicle in driving. In order to maintain an effective and save operation of the machine system, there is a need for the machine to understand the human state, especially cognitive state, when the human's operation task demands an intensive cognitive activity. To achieve this need is a complex task, warranting research. This is because the human being behaves in an extremely uncertain manner in terms of the correspondence between expressions and inferred cognitive states. For example, a person's smiling facial expression may not necessarily imply that the person is happy. Therefore, a new paradigm for techniques to understand and measure the human cognitive state is to consider multimodality features of the human operator with a particular idea that both a feature and its context needs to be integrated in any inferring method. In this paper, we present a method for multimodality inferring of human cognitive states by integrating neuro-fuzzy network and information fusion techniques. To demonstrate the effectiveness of this method, we take the driver fatigue detection as an example due to its important social significance.

It is well known that the driver fatigue is responsible for a relatively high proportion of road traffic accidents. The United States National Highway Traffic Safety Administration (NHTSA) estimates that there are about 100 000 crashes every year caused by the fatigue that have led to more than 1 500 fatalities and 71 000 injuries [1]. Some other statistics