Watermark-Based Replay Attack Detection for Unmanned Marine Vehicles

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Abstract. This paper is concerned with the problem of attack detection for unmanned marine vehicles (UMVs) suffering from replay attacks. As a highly automated equipment, UMVs play the pivotal role in maritime operations. However, due to the complexity of UMVs working environments and the openness and vulnerability of networks, they are susceptible to external disturbances, communication interference, and network attacks. Among various forms of attacks, replay attacks, due to not requiring knowledge of the targeted system's model by the attacker, are easy to execute. Sourced from normal system operation, the data replayed inherently possesses a certain level of stealthiness. The danger lies in attackers not needing to deeply understand the specific operational patterns and objectives of UMVs, nor having to crack the system monitoring devices of UMVs. Attacks can be launched simply by modifying transmitted information, thereby disrupting the normal operational state of UMVs. Therefore, it is of great significance to detect replay attacks promptly and efficiently. To this end, an attack detection scheme based on watermark signals is proposed. Firstly, a Takagi-Sugeno (T-S) fuzzy system model for the UMV are established. Using multiple fuzzy subsystems to approximate the nonlinear UMV system facilitates subsequent research. Then, encoded and decoded signals based on the watermark signal are constructed, which are added to terminals of the sensors and the state estimators to detect replay attacks. The signals can effectively affect the residual values of the system when it is under attack, thus enabling the detection of replay attacks. Moreover, the method contributes to less system performance loss is demonstrated. Finally, the simulation results verify the effectiveness of this scheme.

Keywords: Replay attack detection, unmanned marine vehicles (UMV), Takagi-Sugeno (T-S) fuzzy system, watermark signal.