Digital Twin for the Formal Analysis of a Depth of Anaesthesia Controller

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Abstract

Effective management of depth of anaesthesia (DoA) is crucial for patient safety in healthcare. Anaesthesiologists typically adjust anesthetic dosages to maintain desired sedation, analgesia, and muscle relaxation states. In this paper, we present a digital twin (DT) architecture for the formal modeling and verification of an infusion pump controller for DoA management. The DT incorporates a virtual patient model, an autonomous DoA controller adjusting the infusion rate of the anaesthetic agent, i.e. propofol, a test case manager, and a runtime monitor. Data exchange takes place via ethernet frames. Challenges arise from noise in the Bisprectal Index (BIS) monitoring system readings and infusion rate measurements in clinical scenarios. To mitigate noise impact, we design a feedback controller that is robust against noise. We reason about DT performance by evaluating control specifications using a formal temporal logic language and a formal runtime verification tool.

Keywords

digital twins, formal analysis, runtime verification, health-care, co-simulation, depth of anaesthesia