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Digital Twin Modeling for Enhanced Operational Reliability: A case study on a dredging perception system

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A decision-making system provides system state conditions and general operation instructions to operators based on all available sensing data. This can effectively assist the operators in these decision-making on how to proceed but high reliability of the perception system is, then, crucial.

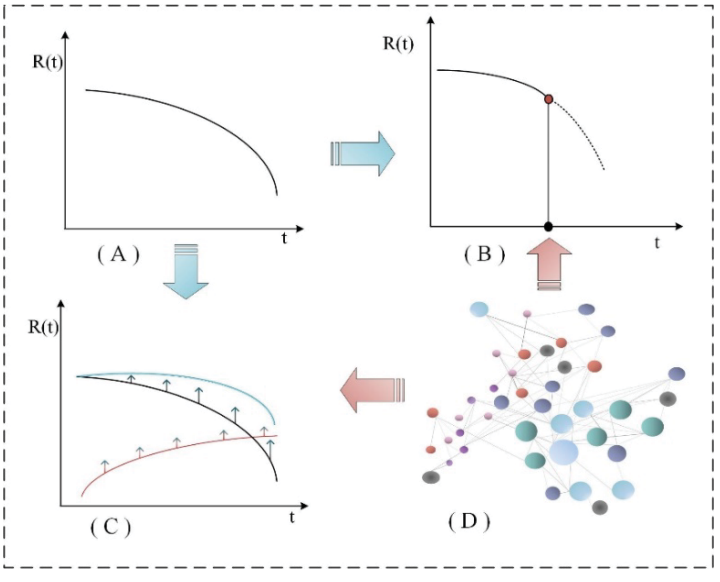

Fig.1 Schematic diagram. Fig.1 (A) depicts the operational reliability of the perception system through a time-varying curve. Fig.1 (B) depicts how, in the event of a sudden failure resulting in operational reliability R=0, represented as “0 states”, the system swiftly recovers its reliability by employing a DT model. To improve system reliability, the DT values and measurement values are fused in state (1, 0), as illustrated by

the red and black curves, respectively. The fused values are shown in blue (C). The DT model is constructed using sensor data obtained from the perception system (D).

As shown conceptually in Fig. 1, we consider the service life, as divided in three states according to the principle of operational reliability. In the first state, the sensing equipment is newly installed and calibrated, and all performance indicators are in the optimal state, defined as the reliability state $R = 1$. In the second state, in which the operational reliability state is $R = (1, 0)$, the performance of the sensing instrument gradually declines over time. The third state, labeled as the "0 state", indicates operational reliability $R = 0$. This occurs when one or more key sensing instruments of the system have sudden failure or reach the specified service life, causing the system to fail to perform assigned tasks (Fig. 1B); this leads to future of the perception system's reliability.

To represent this process, we propose a data-driven approach to establish a digital twin (DT) model of the perception system (Fig. 1D), which can increase in reliability with the service time of the perception system (Fig. 1C). By implementing this model during the "1 state" or "(1,0) state", we can effectively slow down the decline in operational reliability and prolong the system's working life in the second stage, while also preventing the system from entering the third state (of future) during the service period. To validate the effectiveness of our approach, we present a case study of a dredging perception system.

Keywords: Reliability; Digital twin; Data-Driven Model; Information Fusion; Dredging; Perception System.

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