A PINN-Based Digital Parameter Identification of the Pipe Conveying Fluid Systems

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Digital twins are being developed for the monitoring, maintenance planning and operation optimization of industrial systems such as hydraulic infrastructures. Most hydraulic turbines are equipped with many different sensors, such as accelerometers and pressure sensors, to monitor the health condition of the equipment. Machine learning method has been more widely used with the increase of data availability and requirement. However, in most cases, adequate data are not always available, while the limited available data are often noisy and scattered. This study introduces a new method based on physics-informed neural networks (PINN), which takes advantage of the prior physical knowledge of the system in addition to the sensor data and compensates for the sparse data condition to perform parameter identification. A pipe conveying fluid system is considered as the case study to develop a digital twin for, because it is simple to build and exhibits a diverse range of complex behaviors which can be analogous to this of a hydraulic turbine, such as water-added mass, flutter, flow-induced excitation or hydrodynamic damping. Both experimental data and prior knowledge, such as partial differential equations, are used during the training to optimize the weights and biases of the PINN model. Physical prior knowledge is softly encoded by penalizing the residuals of the partial differential equation and the initial and boundary conditions in the loss function. The loss is also composed of the experimental data and is minimized during the training to fit the data as well as the physical model. The physical part of PINN significantly reduces the need for data, limits the impact of over-fitting, and allows for better prediction of the deflection of the pipe conveying system. This method can also solve the inverse problem by optimizing parameters in the partial differential equation, such as the flow rate in the pipe conveying system. In conclusion, the developed PINN-based digital twin not only provides information on the system over time but also infers its hidden characteristics and detects different phenomena.

Keywords: Digital twin, Physics-informed neural networks, Pipe conveying system, Flow rate