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Forward-Reverse Interactive LSTM Networks: A New Paradigm for Distributed Optical Fiber-Based Fracture Monitoring

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Annotation. *This research addresses the challenges of crack parameter inversion in hydraulic fracturing monitoring using distributed optical fiber sensing (DOFS) technology.*
A novel Forward-Reverse Interactive Long Short-Term Memory (FRI-LSTM) model is proposed, which improves upon traditional LSTM by incorporating bidirectional feature interaction and a synergistic optimization mechanism. The study highlights the model's ability to effectively extract fracture parameters from complex strain data, advancing the application of deep learning in DOFS-based monitoring. The findings have broader implications for fields requiring precise time-series analysis, such as pipeline integrity assessment and seismic signal interpretation.
Keywords: *Fracture Monitoring; Deep Learning; Fracture Parameter Inversion; Hydraulic Fracturing; Distributed Optical Fiber*

Distributed optical fiber sensing (DOFS) technology offers significant advantages for hydraulic fracturing crack monitoring, including high spatial resolution, extended range, and resistance to electromagnetic interference, making it an essential tool for subsurface fracture characterization [1]. However, extracting accurate crack geometric parameters from DOFS data remains challenging due to the inherent complexity of strain signals, overlapping patterns, and noise interference [2]. To address these limitations, this study introduces a novel Forward-Reverse Interactive Long Short-Term Memory (FRI-LSTM) model, designed to enhance feature learning capabilities and improve predictive accuracy [3]. By integrating bidirectional feature interaction and a synergistic optimization mechanism, the FRI-LSTM extends the traditional LSTM framework, enabling it to model complex strain data more effectively and accurately predict critical fracture parameters such as length, inlet width, and average width.

Extensive comparative experiments demonstrate the model's superior performance, achieving a 47% reduction in both Mean Absolute Error (MAE) and Root Mean Square Error (RMSE), while boosting the coefficient of determination (R2) from 0.6179 to 0.7500. This study not only advances the application of deep learning in DOFS-based crack monitoring but also establishes a robust foundation for addressing similar challenges in fields requiring precise time-series analysis, including pipeline integrity assessment, structural health monitoring, and seismic signal interpretation.

References

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