A slice-level software vulnerability detection method based on hyperbolic gated graph neural network

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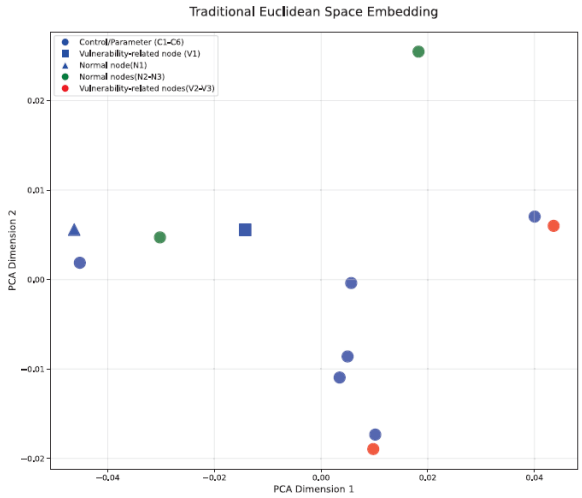
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Problems & Ideas

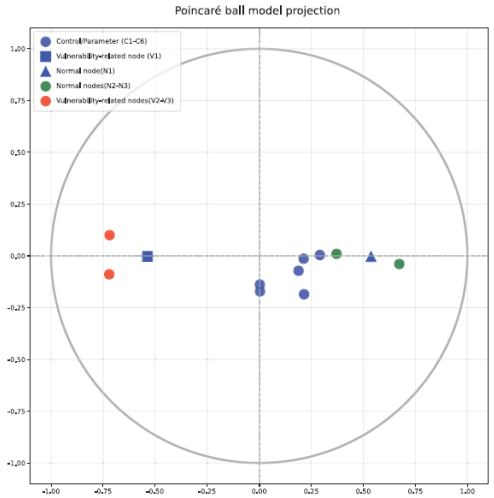
- Current Problems:

  Traditional GNN-based vulnerability detection methods are trained in Euclidean space, failing to model the tree-like hierarchy and power-law degree distribution of PDG, thus causing uneven information propagation, aggravated over-smoothing and limited embedding space.

- Ideas: By introducing a hyperbolic negative-curvature gated graph neural network and a trainable curvature strategy, we can accurately model the hierarchical structure of code and efficientlv extract vulnerabilitv features.



(a) Euclidean space embedding

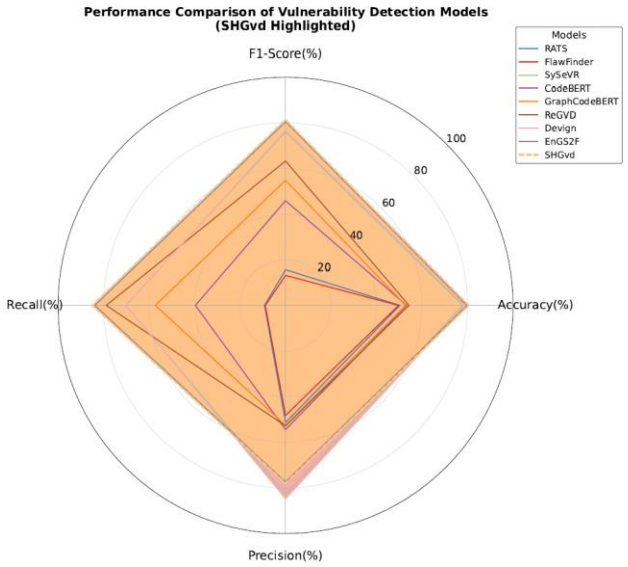


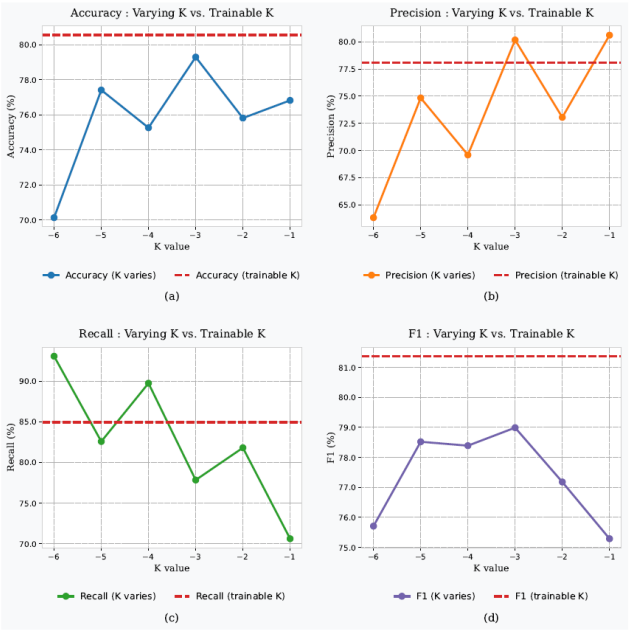
(b) Hyperbolic space embedding

When evaluating the performance of embedded node features in terms of spatial structure, clustering capability, and distinguishability of key features, Euclidean space embedding (on the left) significantly underperforms compared to hyperbolic space embedding (on the right).

Main Contributions

- Contributions:
  - A novel approach for vulnerability detection in source code, is proposed, which leverages source code graph slicing data and a hyperbolic space gated graph neural network architecture;
  - A graph neural network model adapted to hyperbolic space and featuring trainable curvature parameters is introduced;
  - Evaluated on the Big-Vul dataset against 8 mainstream baseline methods.





Left:Comparison of experimental results with other baseline methods; Right: xperimental comparison of trainable curvature versus fixed curvature configurations.