



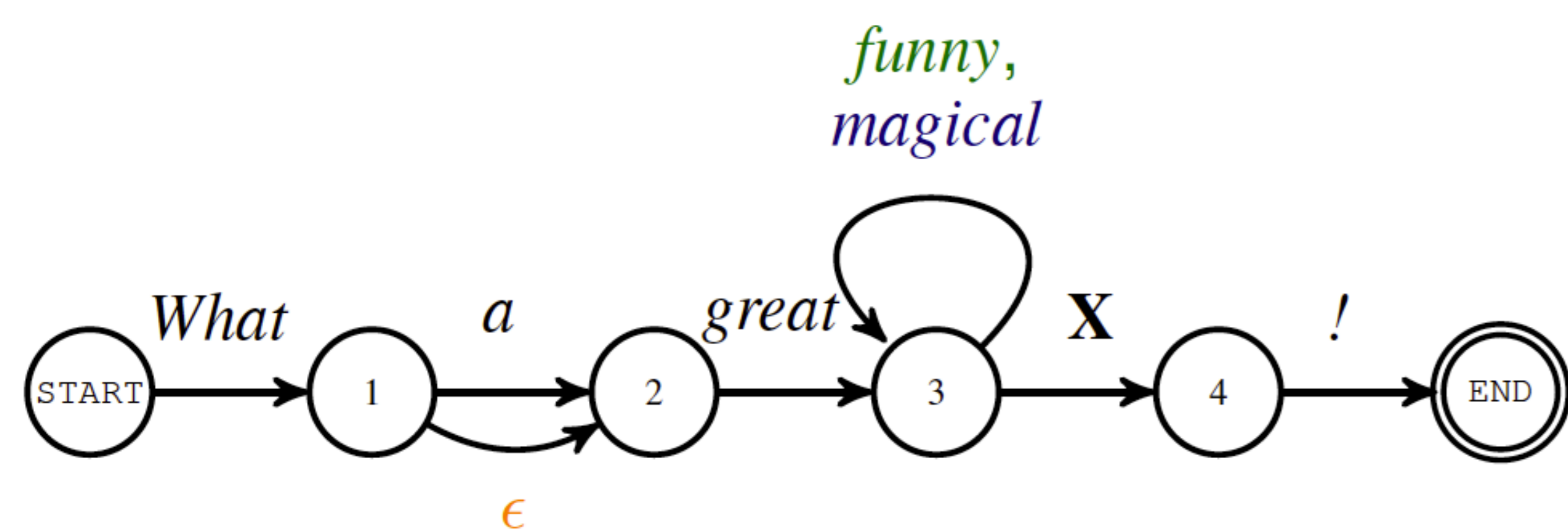
SoPa: Bridging CNNs, RNNs, and Weighted Finite-State Machines

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SoPa: Soft Patterns



- What a great **movie** !
- What a great **book** !
- What great **shoes** !
- What a great, **funny, magical** show !

Pattern Matching using
Weighted Finite State Automata (WFSAs)

Neural Transitions in WFSAs

Main path

$$[\mathbf{T}(x)]_{i,j} = \begin{cases} \sigma(\mathbf{u}_i \cdot \mathbf{v}_x + a_i), & \text{if } j = i \text{ (self-loop)} \\ \sigma(\mathbf{w}_i \cdot \mathbf{v}_x + b_i), & \text{if } j = i + 1 \\ 0, & \text{otherwise,} \end{cases}$$

ε-transitions

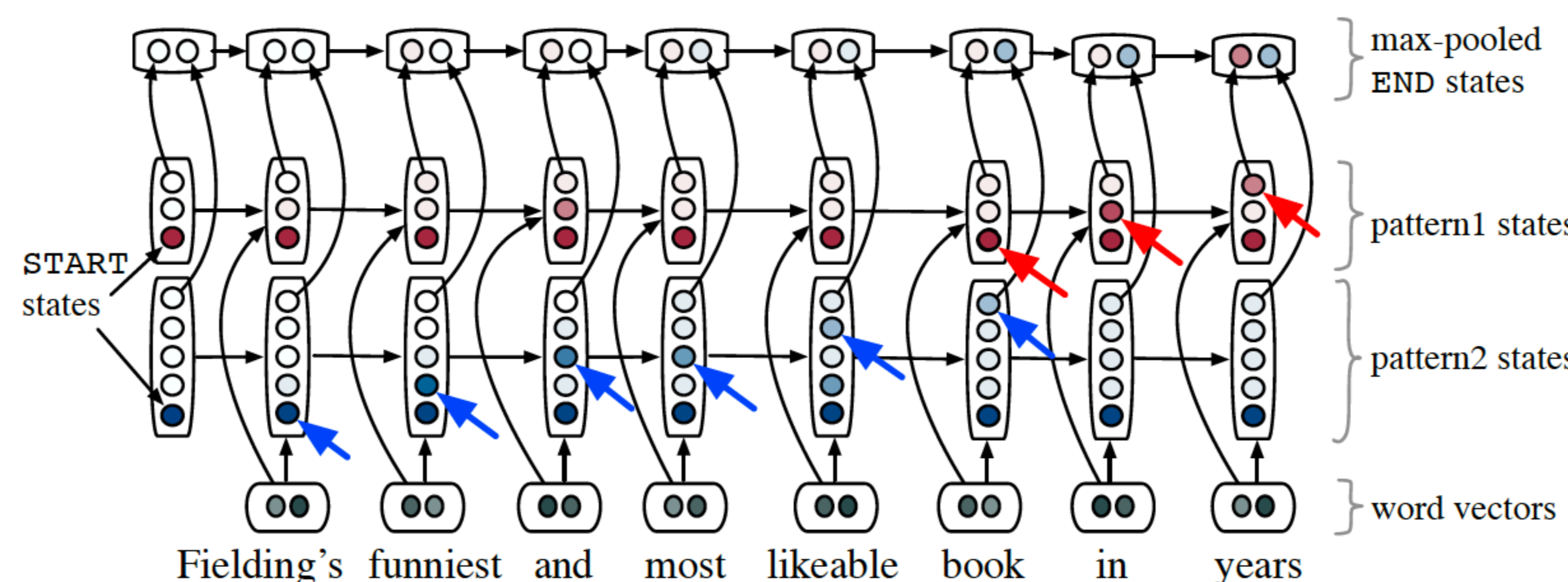
$$[\mathbf{T}(\epsilon)]_{i,j} = \begin{cases} \sigma(c_i), & \text{if } j = i + 1 \\ 0, & \text{otherwise,} \end{cases}$$

- A **hidden state** represents the score of the **best path** through the pattern
- Pattern match computed efficiently using **dynamic programming**
- Transition weights explicitly capture a soft notion of **words** and **wildcards**

Takeaways

- A new RNN combining **neural learning** with **WFSAs**
- An extension of a **one-layer CNN**
- Models flexible-length spans with **insertion** and **deletion**
- Can be easily customized by swapping in different **semirings**
- Paving the bridge between **CNNs** and **RNNs**
- https://github.com/Noahs-ARK/soft_patterns

Multiple Patterns in Parallel – an RNN!



Extension of a 1-Layer CNN

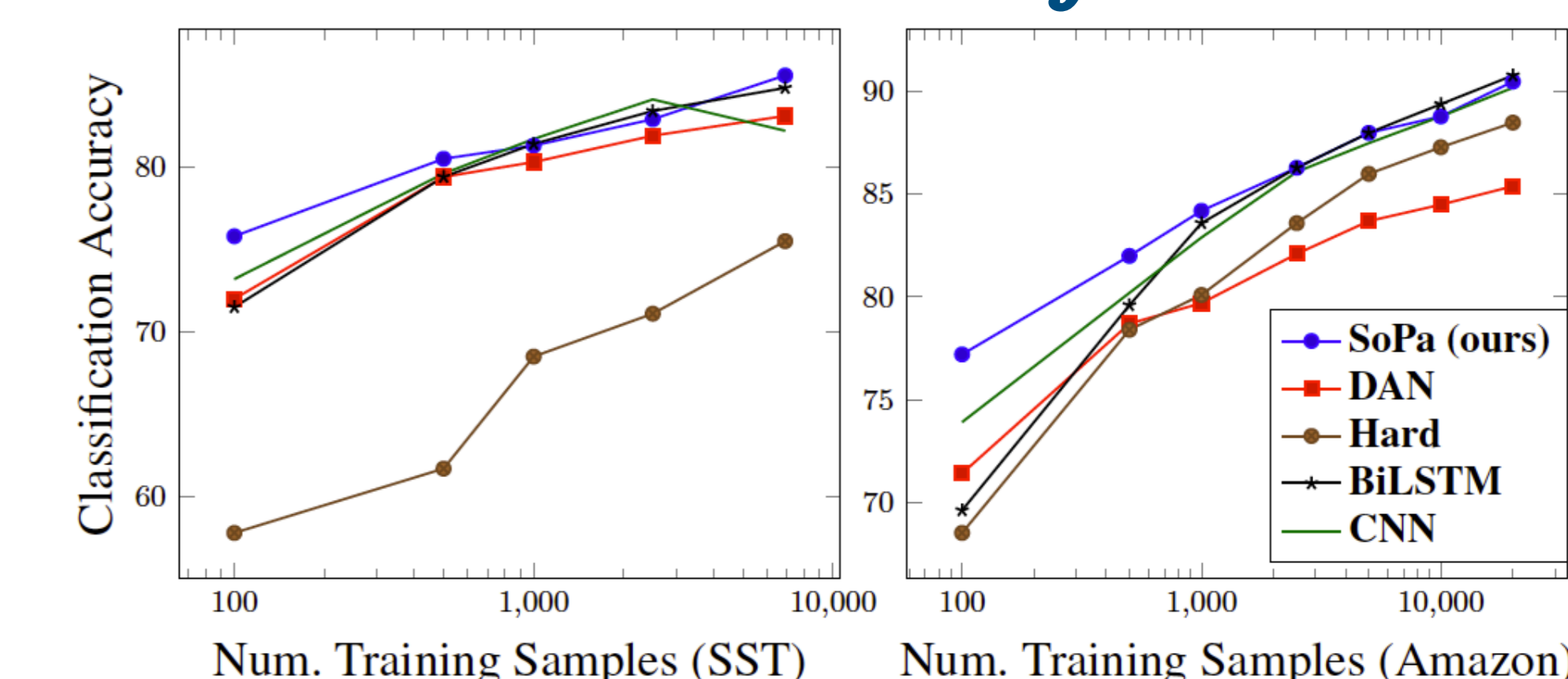
- With **max-plus** semiring, without **self-loops**, **ε-transitions** and the **sigmoid** in the main path transition, SoPa is equivalent to a 1-layer CNN with max-pooling

$$s_{\text{span}}(\mathbf{x}_{i:i+d}) = \sum_{j=0}^{d-1} \mathbf{w}_j \cdot \mathbf{v}_{x_{i+j}} + b_j = \mathbf{w}_{0:d} \cdot \mathbf{v}_{x_{i:i+d}} + \sum_{j=0}^{d-1} b_j$$

$$s_{\text{doc}}(\mathbf{x}) = \max_{1 \leq i \leq n-d+1} s_{\text{span}}(\mathbf{x}_{i:i+d})$$

- A 1-layer **CNN** is also learning a restricted form of a **WFSAs**

Text Cat. Experiments Sentiment Analysis



Interpretation

- SoPa is interpretable both at the **single pattern** level and the **document** level

Highest Scoring Phrases

's ε uninspired story .
this ε bad on purpose
this ε leaden comedy .
a ε half-assed film .
is ε clumsy ,SL the writing

honest , and enjoyable
soulful , scathingsL and joyous
unpretentious , charmingsL , quirky
forceful , and beautifully
energetic , and surprisingly

Analyzed Documents

it 's dumb , but more importantly , it 's just not scary

though moonlight mile is replete with acclaimed actors and actresses and tackles a subject that 's potentially moving , the movie is too predictable and too self-conscious to reach a level of high drama

While its careful pace and seemingly opaque story may not satisfy every moviegoer 's appetite, the film 's final scene is soaringly , transparently moving