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ENROL

NEURAL INFORMATION PROCESSING SYSTEMS

Scaling Up Liquid-Resistance Liquid-Capacitance Networks for Efficient Sequence Modeling

Mónika Farsang, Radu Grosu

CPS, Technische Universität Wien (TU Wien), Austria

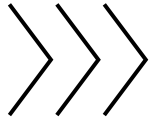
Overview

LRC (Liquid-Resistance Liquid-Capacitance Networks):

- Non-linear recurrent neural network

- ODE model: chemical synapses with flexible membrane capacitance

Re-design



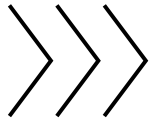
Proposed LrcSSM model:

- Efficient Structured State-Space Model (SSM) version

Overview

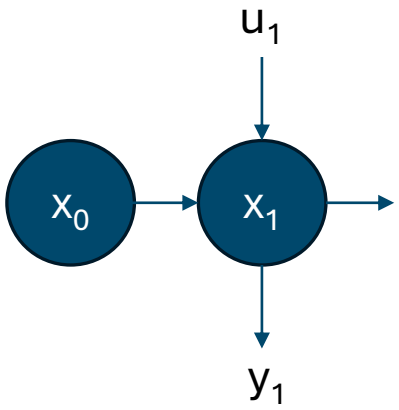
Non-linear Recurrent Neural Networks (RNN)

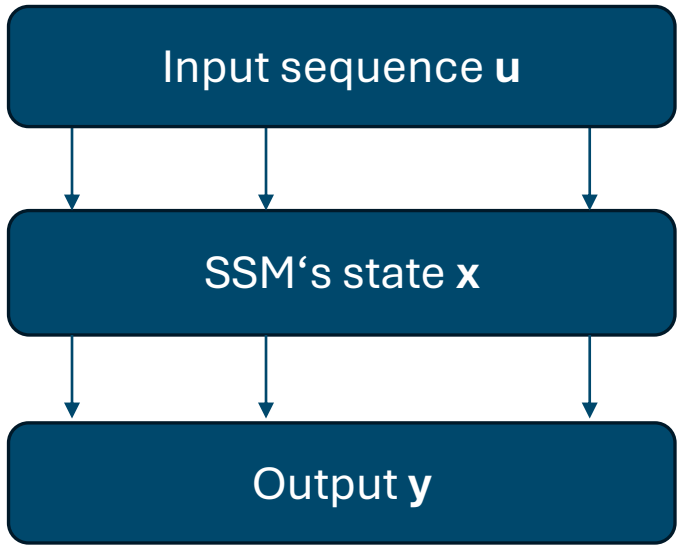
Re-design



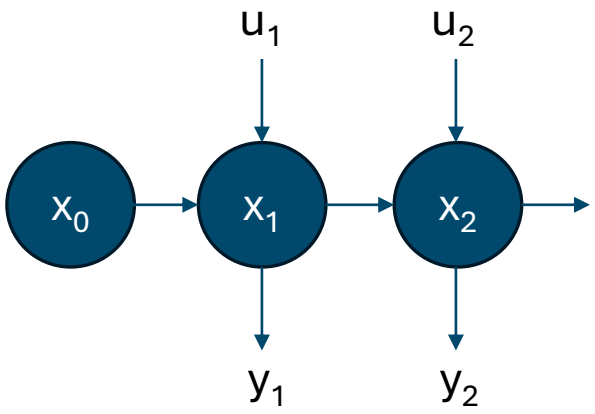
Efficient Structured State-Space Model (SSM) variant

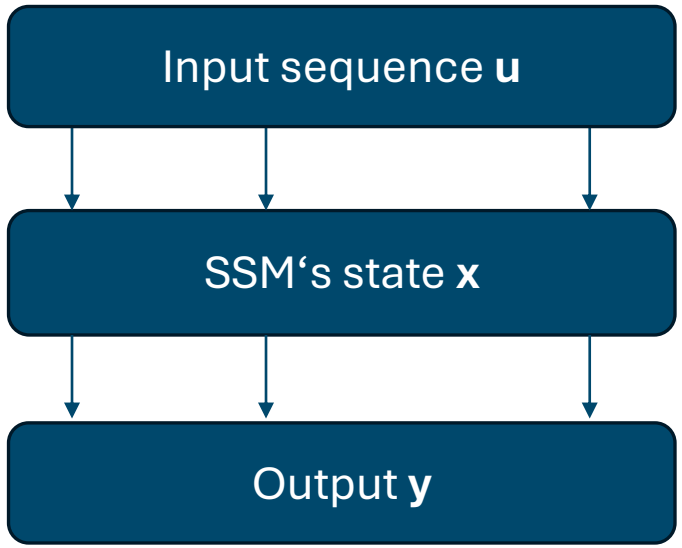
Challenge of Non-linear RNNs





Challenge of Non-linear RNNs





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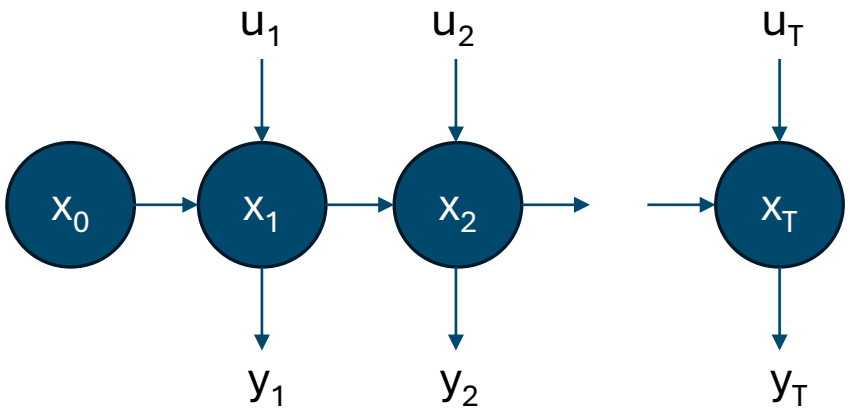

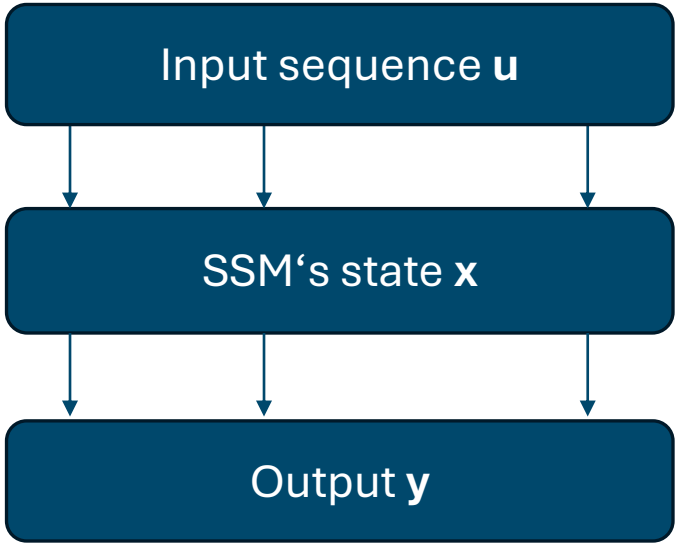

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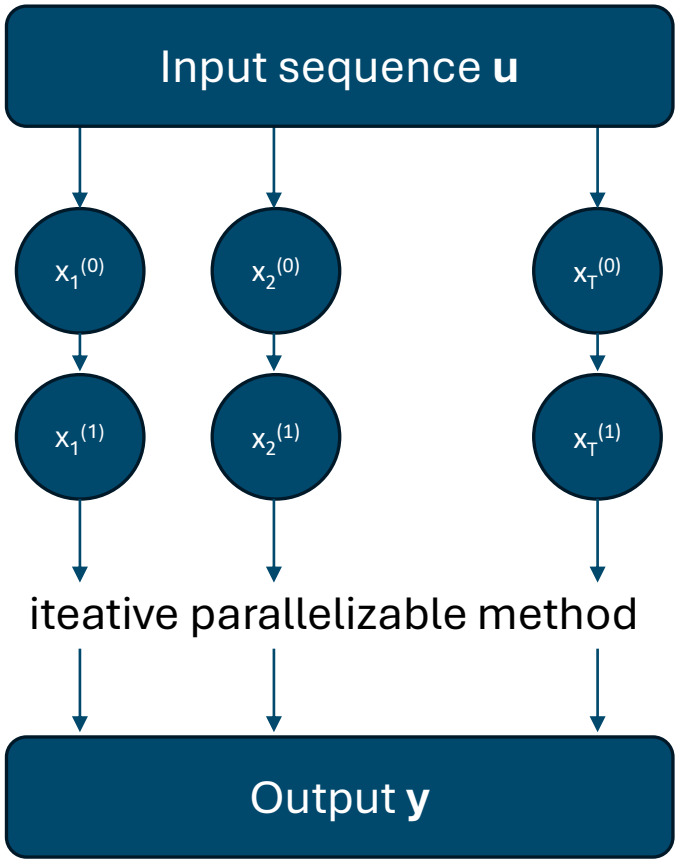
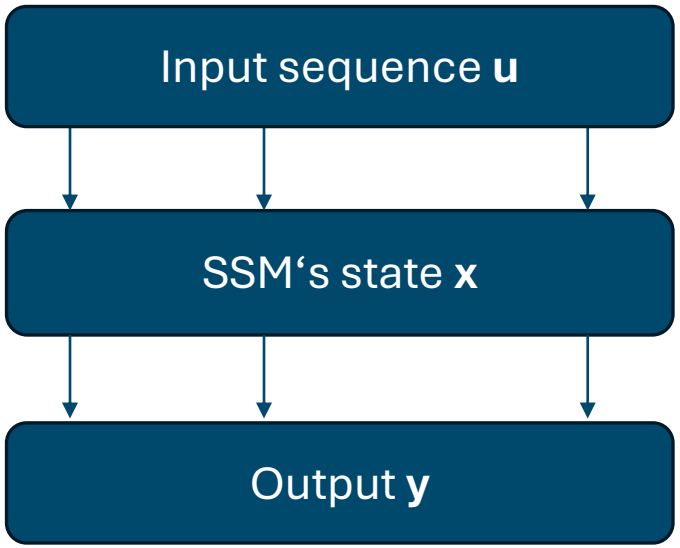
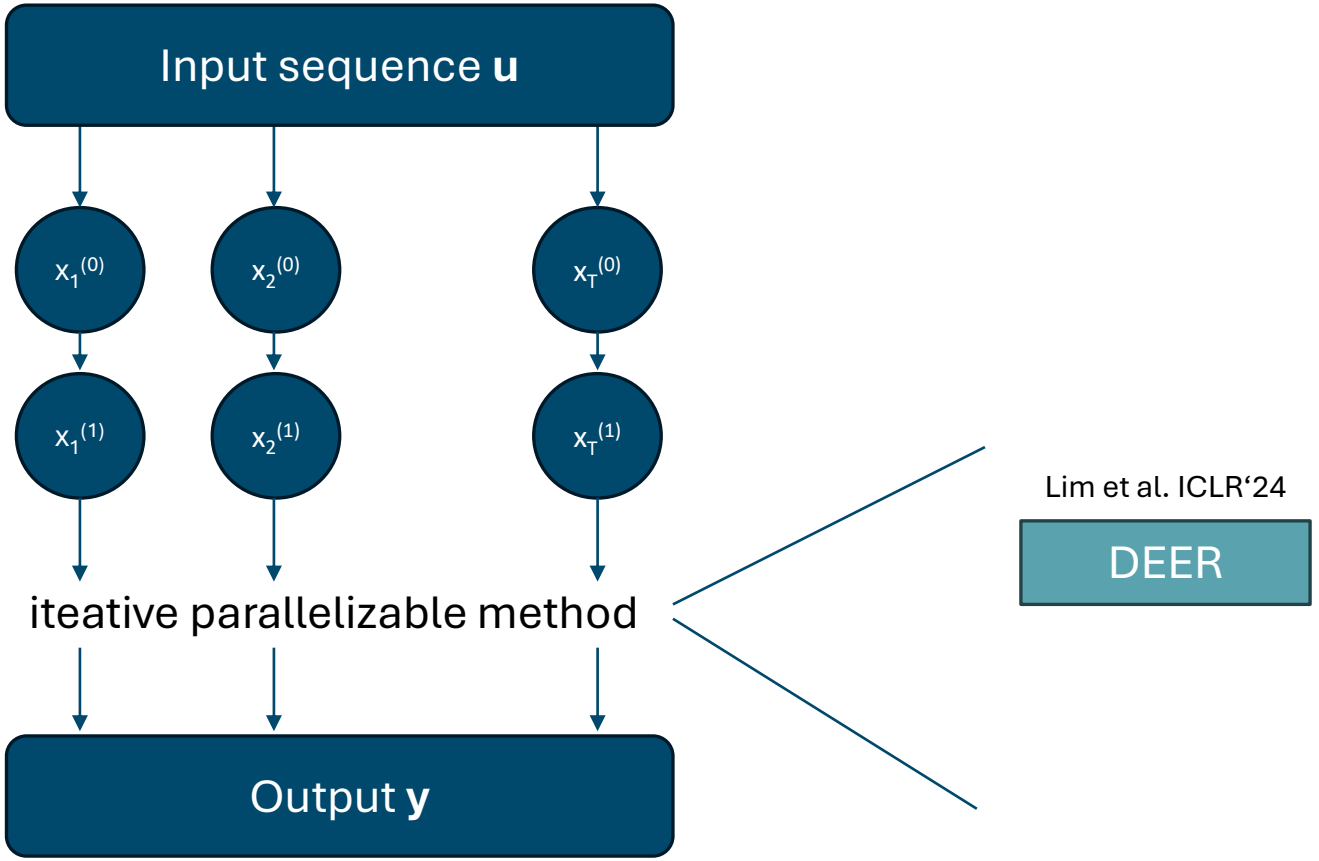
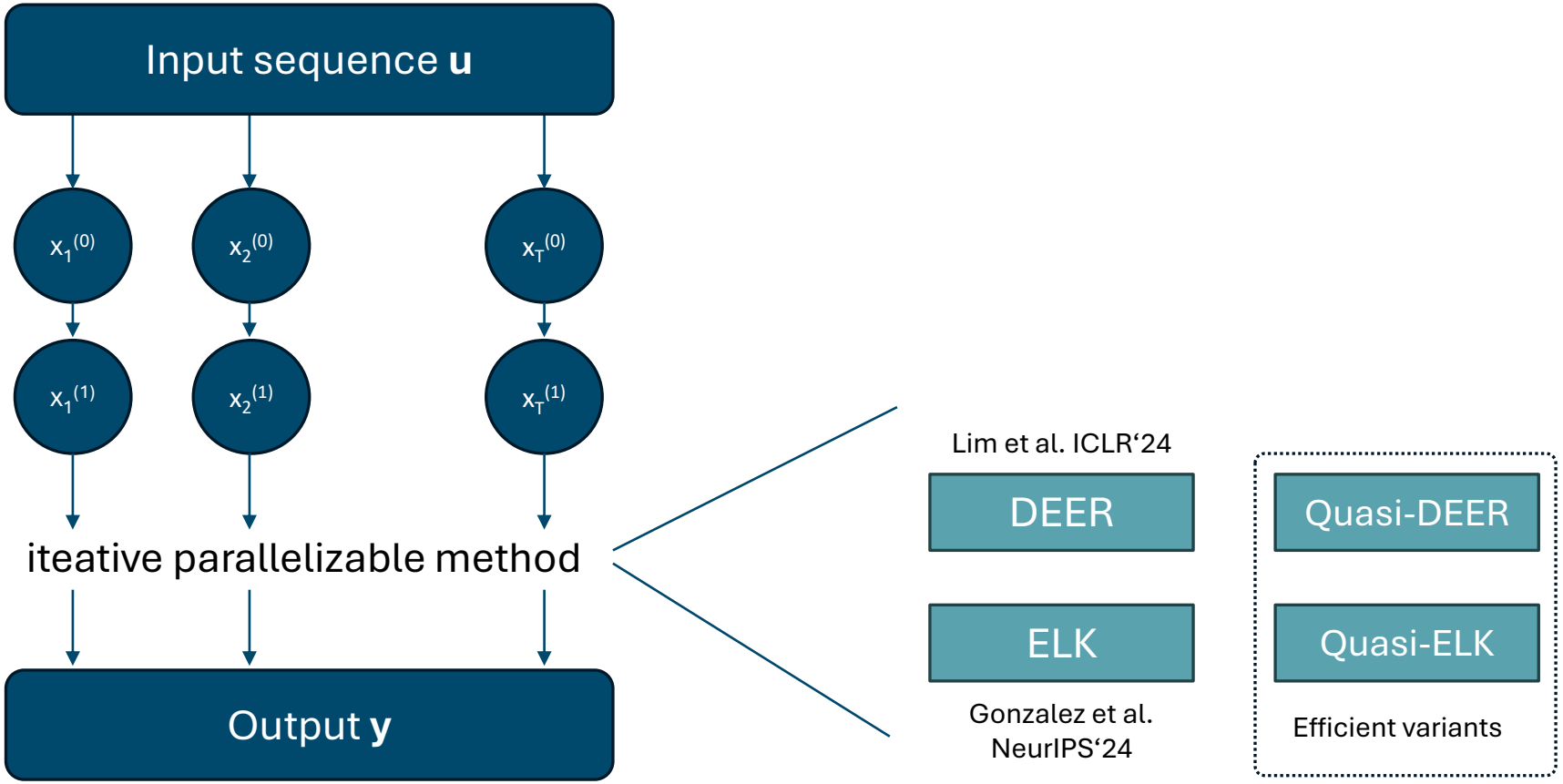




Challenge of Non-linear RNNs



Challenge of Non-linear RNNs



Our Approach

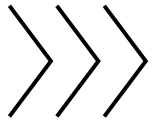
Efficient algorithm without sacrificing exact computations

→ **Model design**

LRC (Liquid-Resistance Liquid-Capacitance Networks):

- Non-linear RNN
- Dense Jacobian matrices
- Not efficient

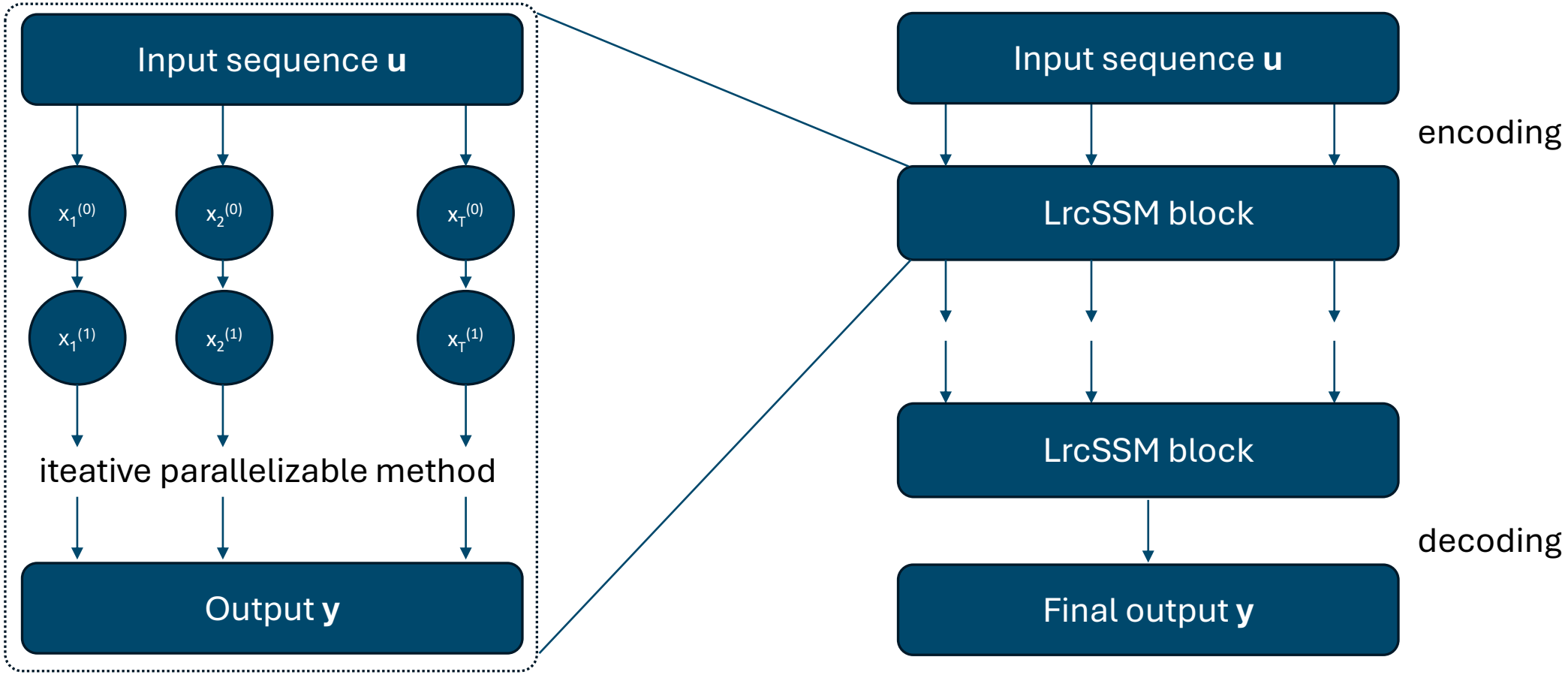
Re-design



Proposed LrcSSM model:

- Non-linear SSM
- Diagonal Jacobian matrices
- Very efficient

Architecture



Experiments

† Rusch et al. ICLR'25,
‡ Moreno et al. NeurIPS'24

	Heart	SCP1	SCP2	Ethanol	Motor	Worms	Average
Sequence length	405	896	1,152	1,751	3,000	17,984	
Input size	61	6	7	2	63	6	
#Classes	2	2	2	4	2	5	
NRDE†	73.9 ± 2.6	76.7 ± 5.6	48.1 ± 11.4	31.4 ± 4.5	54.0 ± 7.8	77.2 ± 7.1	60.2 ± 7.7
NCDE†	68.1 ± 5.8	80.0 ± 2.0	49.1 ± 6.2	22.0 ± 1.0	51.6 ± 6.2	62.2 ± 2.2	55.5 ± 8.1
Log-NCDE†	74.2 ± 2.0	82.1 ± 1.4	54.0 ± 2.6	**35.9 ± 6.1**	57.2 ± 5.6	82.8 ± 2.7	64.4 ± 7.6
LRU†	**78.1 ± 7.6**	84.5 ± 4.6	47.4 ± 4.0	23.8 ± 2.8	51.9 ± 8.6	85.0 ± 6.2	61.8 ± 10.1
S5†	73.9 ± 3.1	**87.1 ± 2.1**	**55.1 ± 3.3**	25.6 ± 3.5	53.0 ± 3.9	83.9 ± 4.1	63.1 ± 9.5
Mamba†	**76.2 ± 3.8**	80.7 ± 1.4	48.2 ± 3.9	27.9 ± 4.5	47.7 ± 4.5	70.9 ± 15.8	58.6 ± 8.4
S6†	**76.5 ± 8.3**	82.8 ± 2.7	49.9 ± 9.4	26.4 ± 6.4	51.3 ± 4.7	85.0 ± 16.1	62.0 ± 9.5
LinOSS-IMEX†	75.5 ± 4.3	**87.5 ± 4.0**	**58.9 ± 8.1**	29.9 ± 1.0	**57.9 ± 5.3**	80.0 ± 2.7	**65.0 ± 8.5**
LinOSS-IM†	75.8 ± 3.7	**87.8 ± 2.6**	**58.2 ± 6.9**	29.9 ± 0.6	**60.0 ± 7.5**	**95.0 ± 4.4**	**67.8 ± 9.7**
Transformer‡	70.5 ± 0.1	84.3 ± 6.3	49.1 ± 2.5	**40.5 ± 6.3**	50.5 ± 3.0	OOM	59.0 ± 8.0
RFormer‡	72.5 ± 0.1	81.2 ± 2.8	52.3 ± 3.7	34.7 ± 4.1	55.8 ± 6.6	**90.3 ± 0.1**	64.5 ± 8.4
LrcSSM (Ours)	72.7 ± 5.7	85.2 ± 2.1	53.9 ± 7.2	**36.9 ± 5.3**	**58.6 ± 3.1**	**90.6 ± 1.4**	**66.3 ± 8.3**

Scaling Up Liquid-Resistance Liquid-Capacitance Networks for Efficient Sequence Modeling

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