大模型系列 – 大模型算法

打破 Transformer

ZOMI

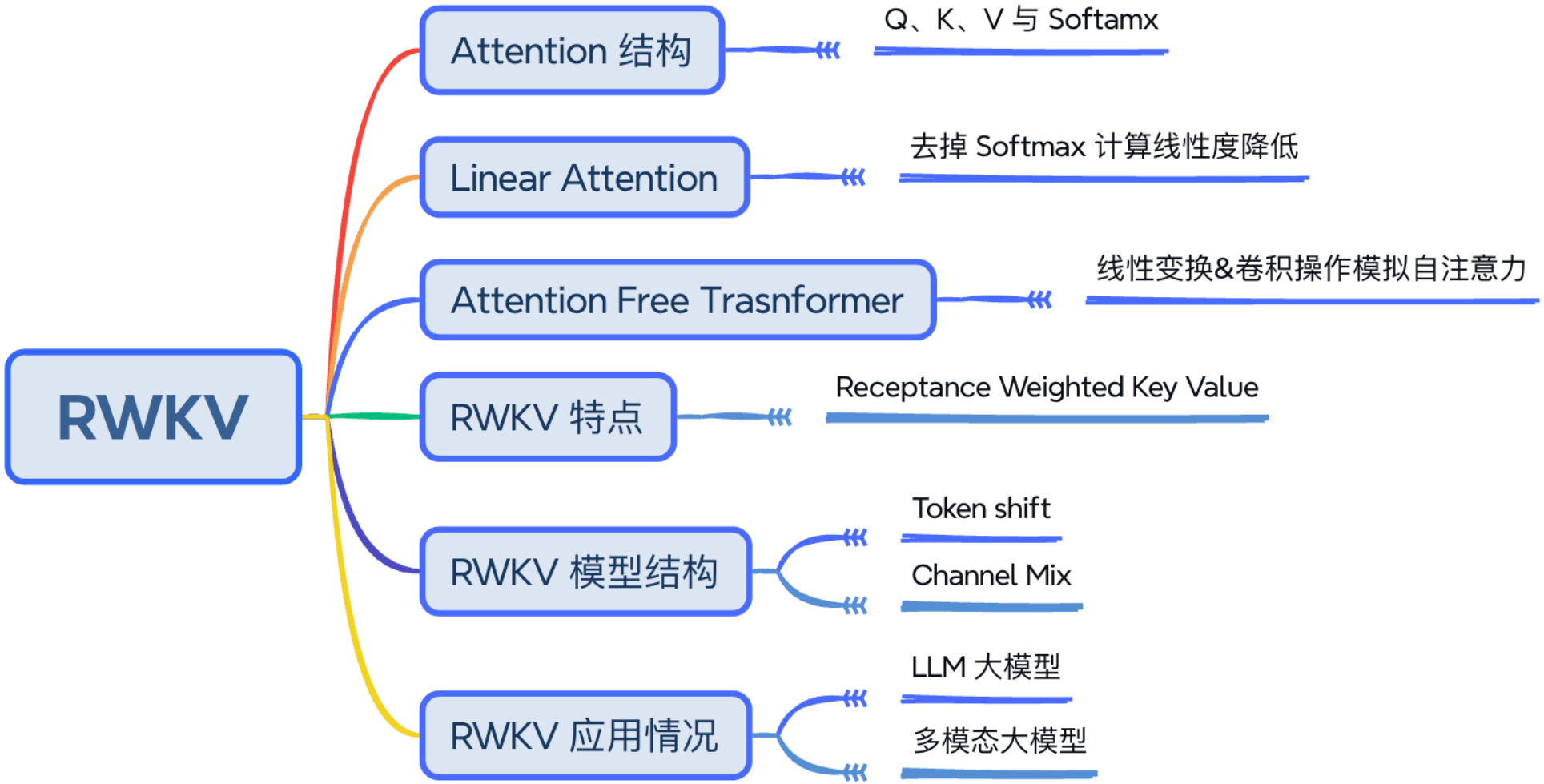
关于本内容

1. Transformer 结构回顾与挑战
2. RWKV 新结构
3. Mamba 新结构
4. 未来打破 Transformer 路在何方

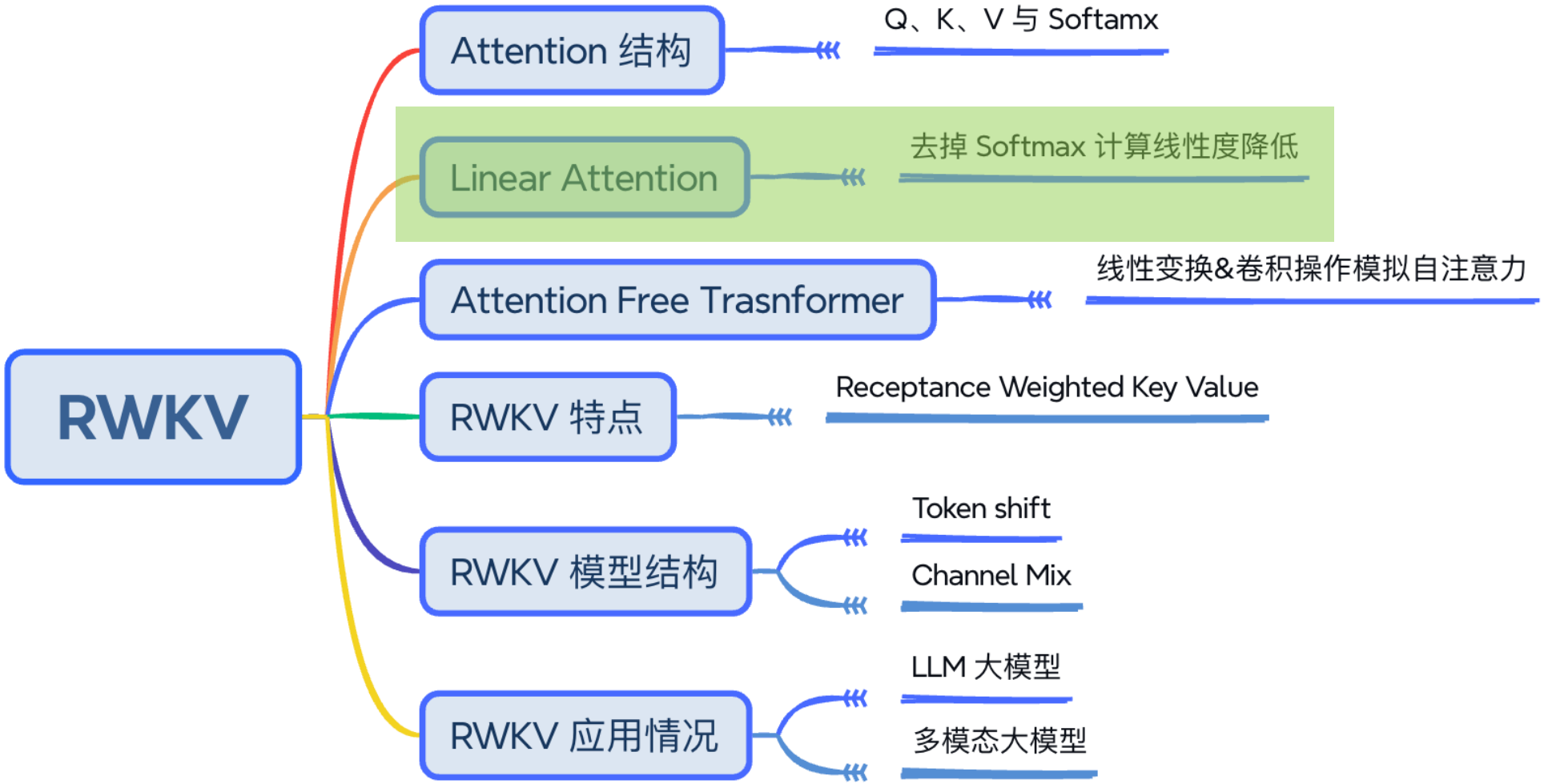
01

RWKV

RWKV


RWKV
Attention 结构
Q、K、V 与 Softamx
Linear Attention
去掉 Softmax 计算线性度降低
Attention Free Trasnformer
线性变换&卷积操作模拟自注意力
RWKV 特点
Receptance Weighted Key Value
RWKV 模型结构
Token shift
Channel Mix
RWKV 应用情况
LLM 大模型
多模态大模型

RWKV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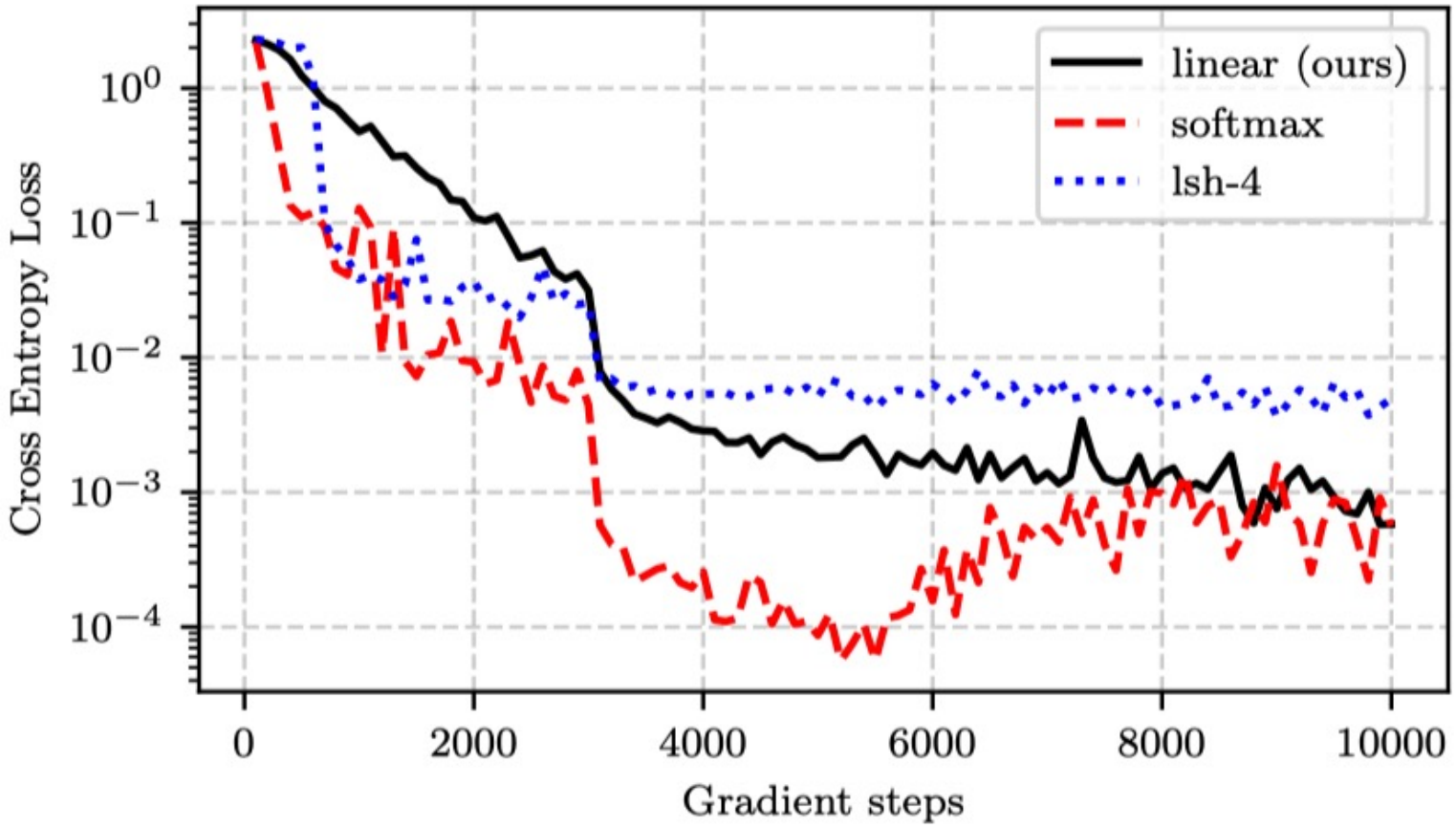
Linear Attention

- Transformers are rnns: Fast autoregressive transformers with linear attention.

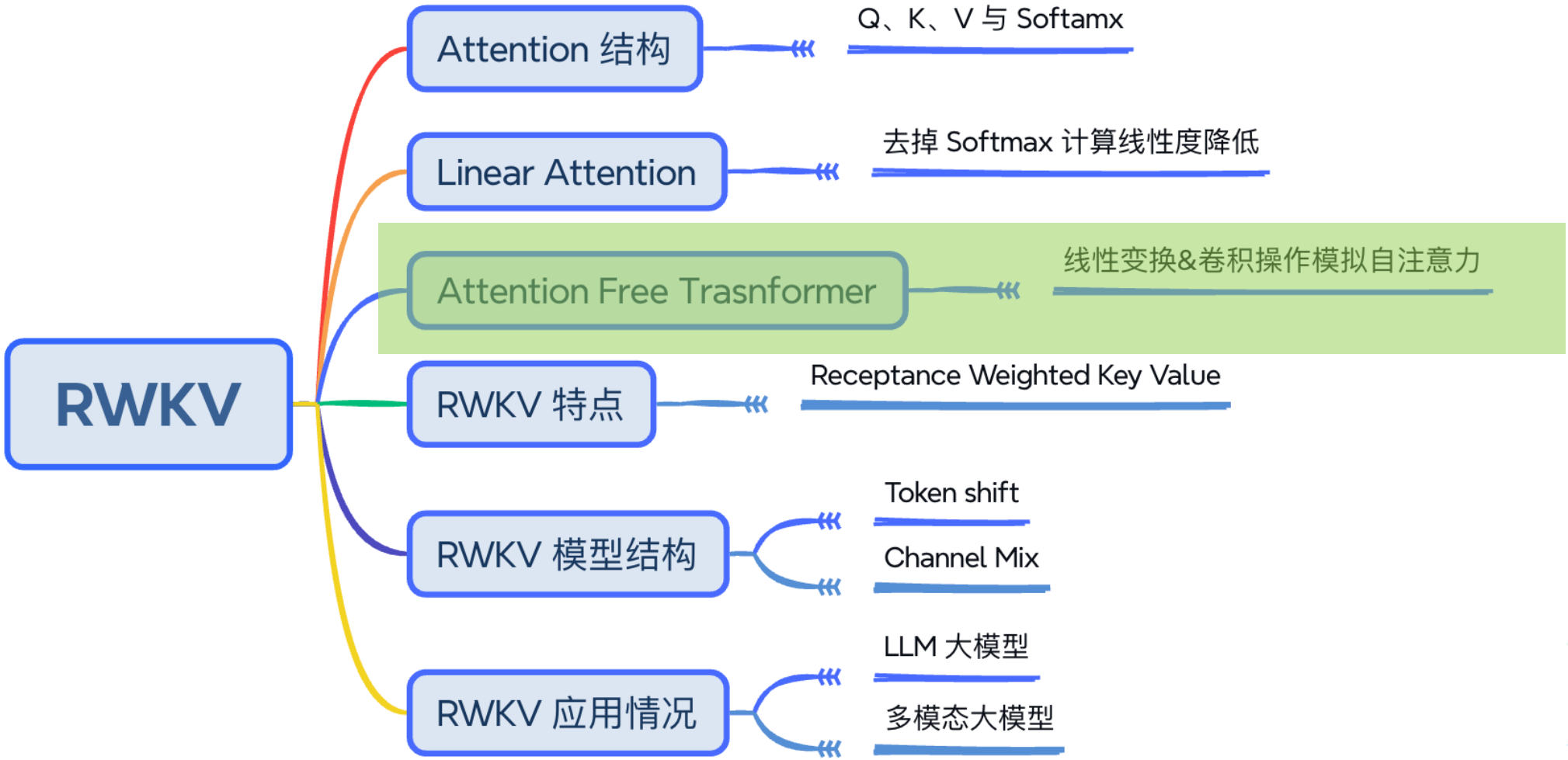
Algorithm 1 Linear transformers with causal masking

function forward $(\phi(Q), \phi(K), V)$**:**
  $V' \leftarrow 0, S \leftarrow 0$
  for $i = 1, \ldots, N$ **do**
    $S \leftarrow S + \phi(K_i) V_i^T$ equation 10
    $\bar{V}_i \leftarrow \phi(Q_i) S$
  end
  return $\bar{V}$
end

function backward $(\phi(Q), \phi(K), V, G)$**:**
  /* G is the gradient of the loss with respect to the output of forward */
  $S \leftarrow 0, \nabla_{\phi(Q)}\mathcal{L} \leftarrow 0$
  for $i = 1, \ldots, N$ **do**
    $S \leftarrow S + \phi(K_i) V_i^T$
    $\nabla_{\phi(Q_i)}\mathcal{L} \leftarrow G_i S^T$ equation 13
  end
  $S \leftarrow 0, \nabla_{\phi(K)}\mathcal{L} \leftarrow 0, \nabla_V \mathcal{L} \leftarrow 0$
  for $i = N, \ldots, 1$ **do**
    $S \leftarrow S + \phi(Q_i) G_i^T$
    $\nabla_{V_i}\mathcal{L} \leftarrow S^T \phi(K_i)$ equation 15
    $\nabla_{\phi(K_i)}\mathcal{L} \leftarrow S V_i$ equation 14
  end
  return $\nabla_{\phi(Q)}\mathcal{L}, \nabla_{\phi(K)}\mathcal{L}, \nabla_V \mathcal{L}$
end



RWKV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AFT

- Paper： An attention free transformer.

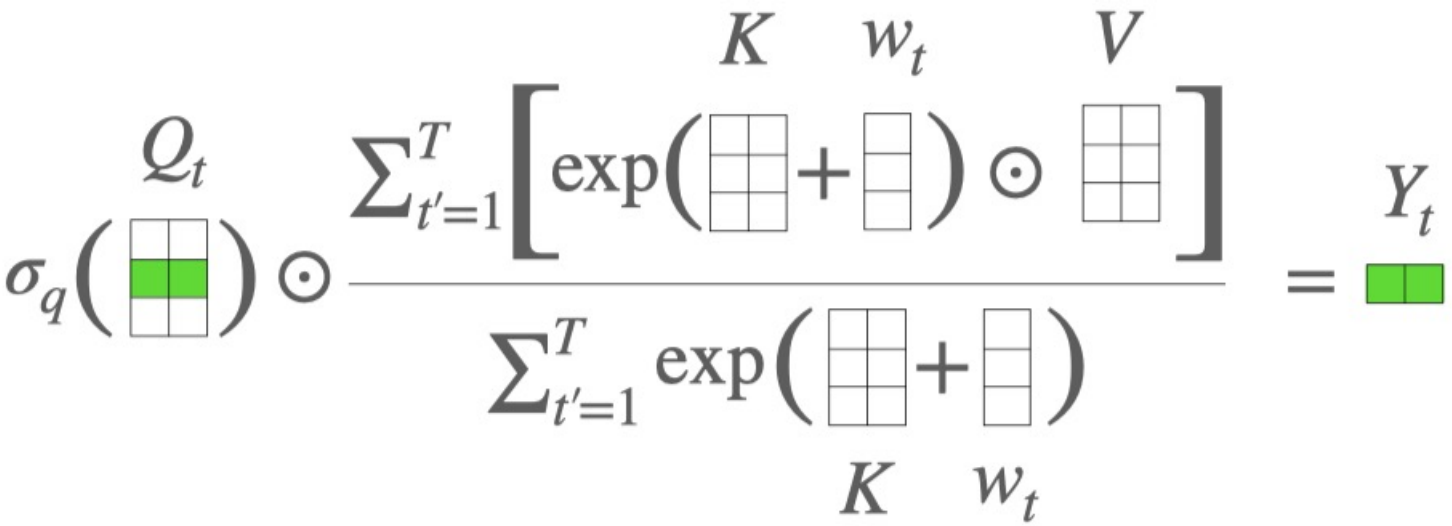
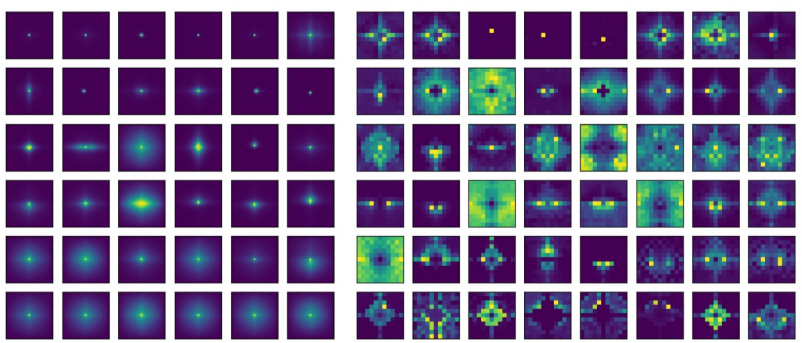


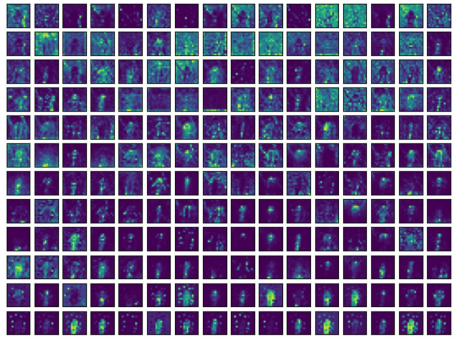
Figure 2: An illustration of AFT defined in Equation 2, with $T = 3, d = 2$.

AFT

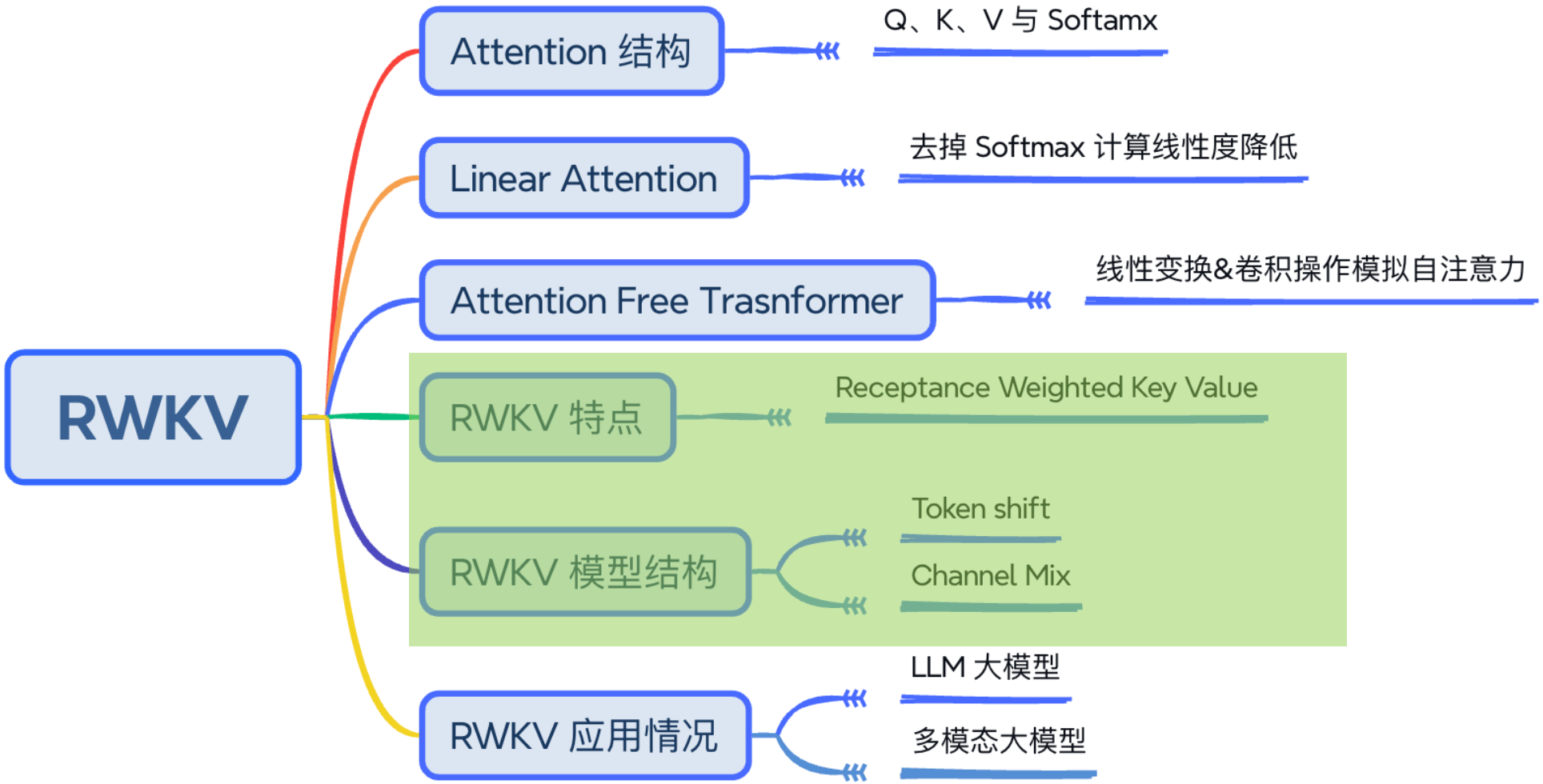
- Paper： An attention free transformer.

Model	Time	Space
Transformer	$O(T^2d)$	$O(T^2 + Td)$
Reformer	$O(T \log Td)$	$O(T \log T + Td)$
Linear Transformer	$O(Td^2)$	$O(Td + d^2)$
Performer	$O(Td^2 \log d)$	$O(Td \log d + d^2 \log d)$
AFT-simple	$O(\mathbf{Td})$	$O(\mathbf{Td})$
AFT-full	$O(T^2d)$	$O(\mathbf{Td})$
AFT-local (AFT-conv)	$O(Tsd),\ s < T$	$O(\mathbf{Td})$





RWKV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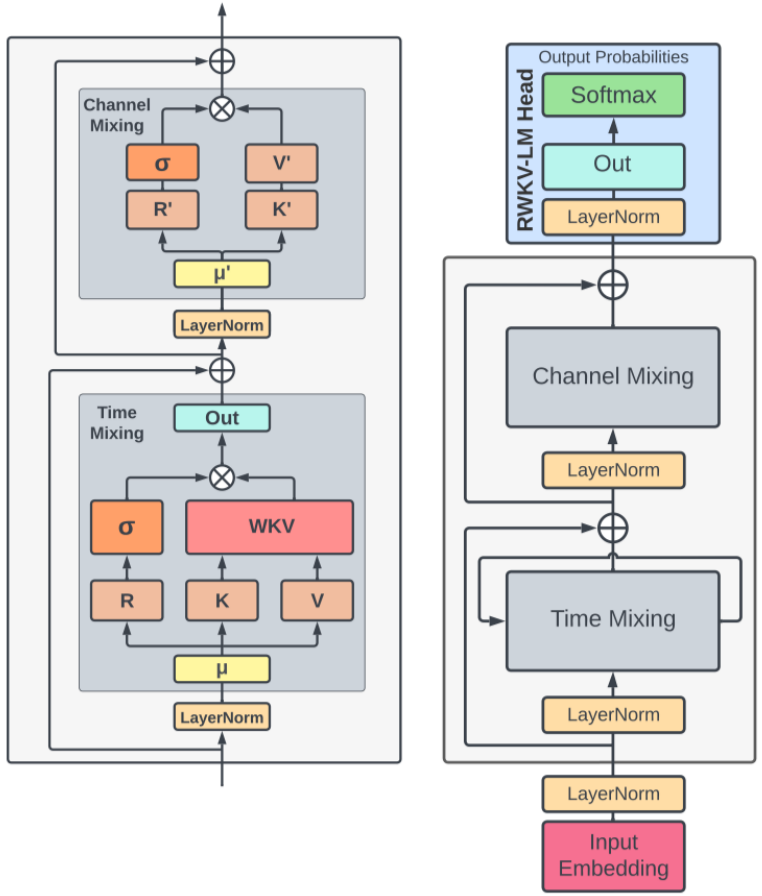
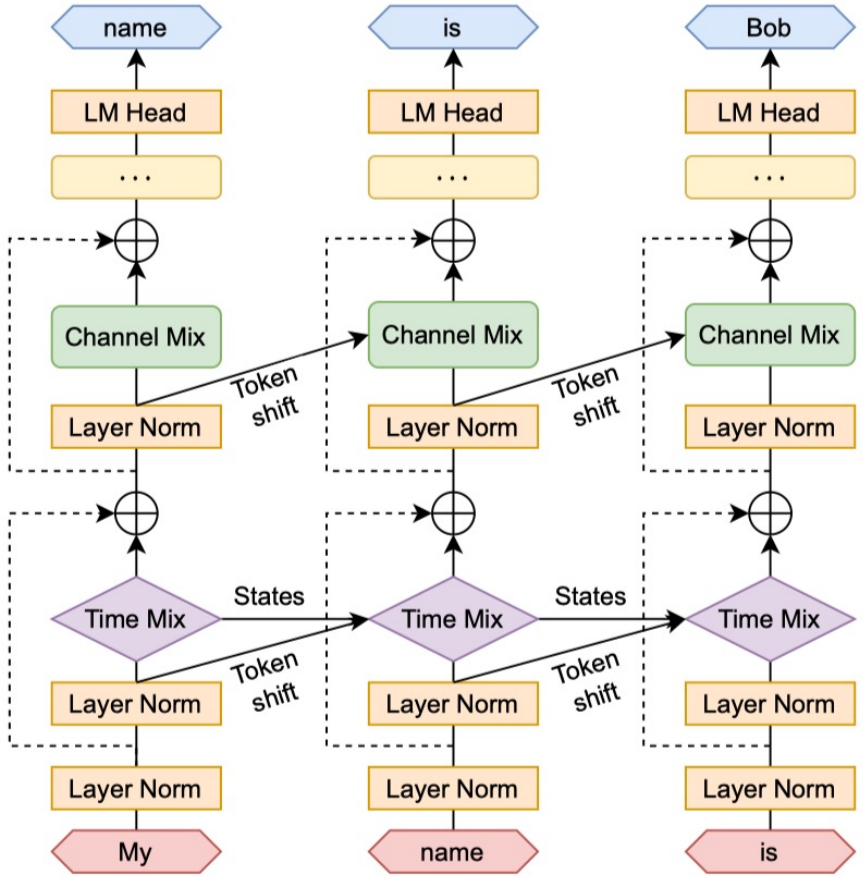
RWKV

- RWKV: Reinventing RNNs for the Transformer Era





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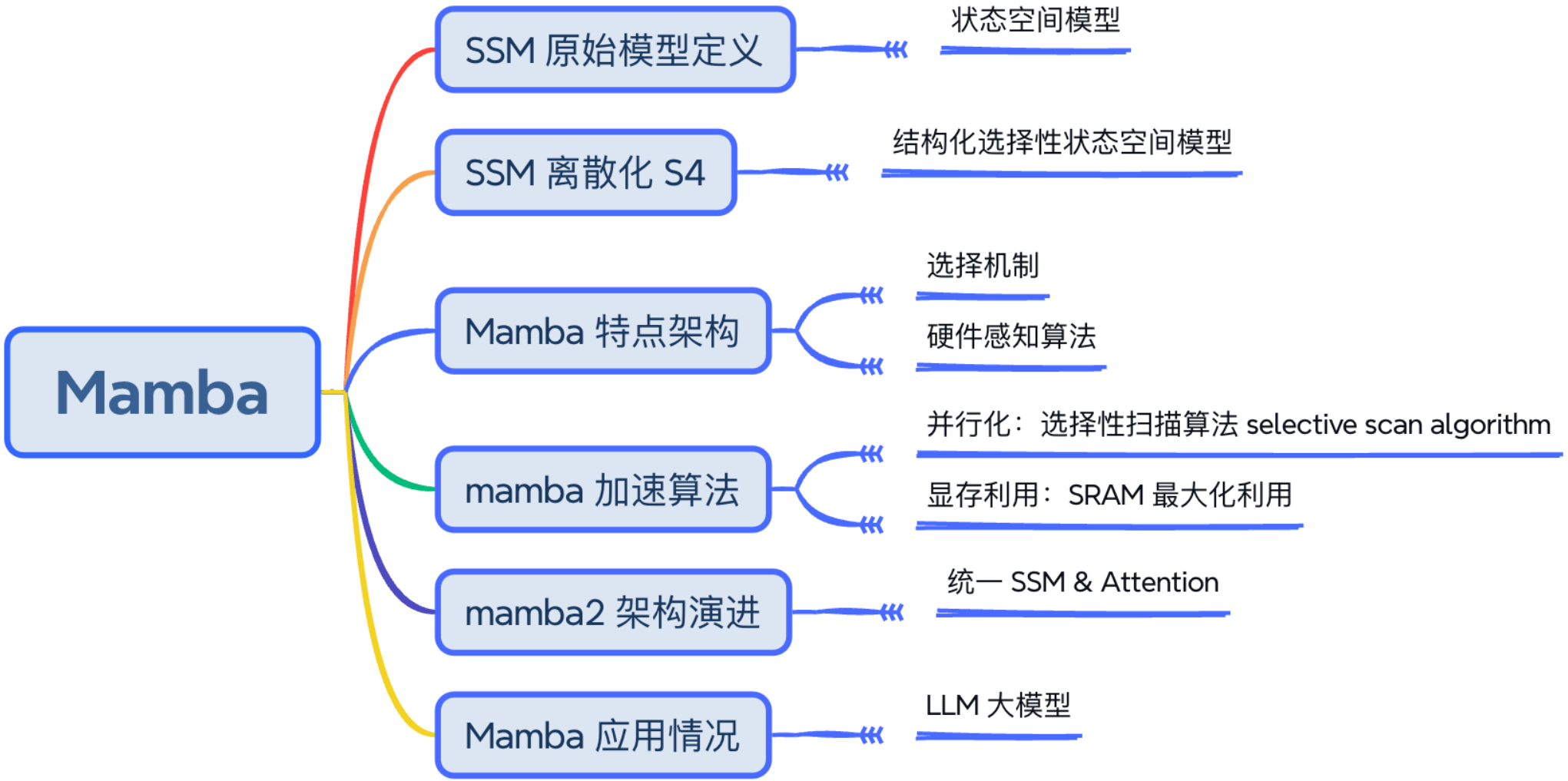
2. https://www.rwkv.com/
3. https://arxiv.org/abs/2105.14103
4. https://github.com/BlinkDL/RWKV-LM
5. https://wiki.rwkv.com/

02 Mamba

Mamba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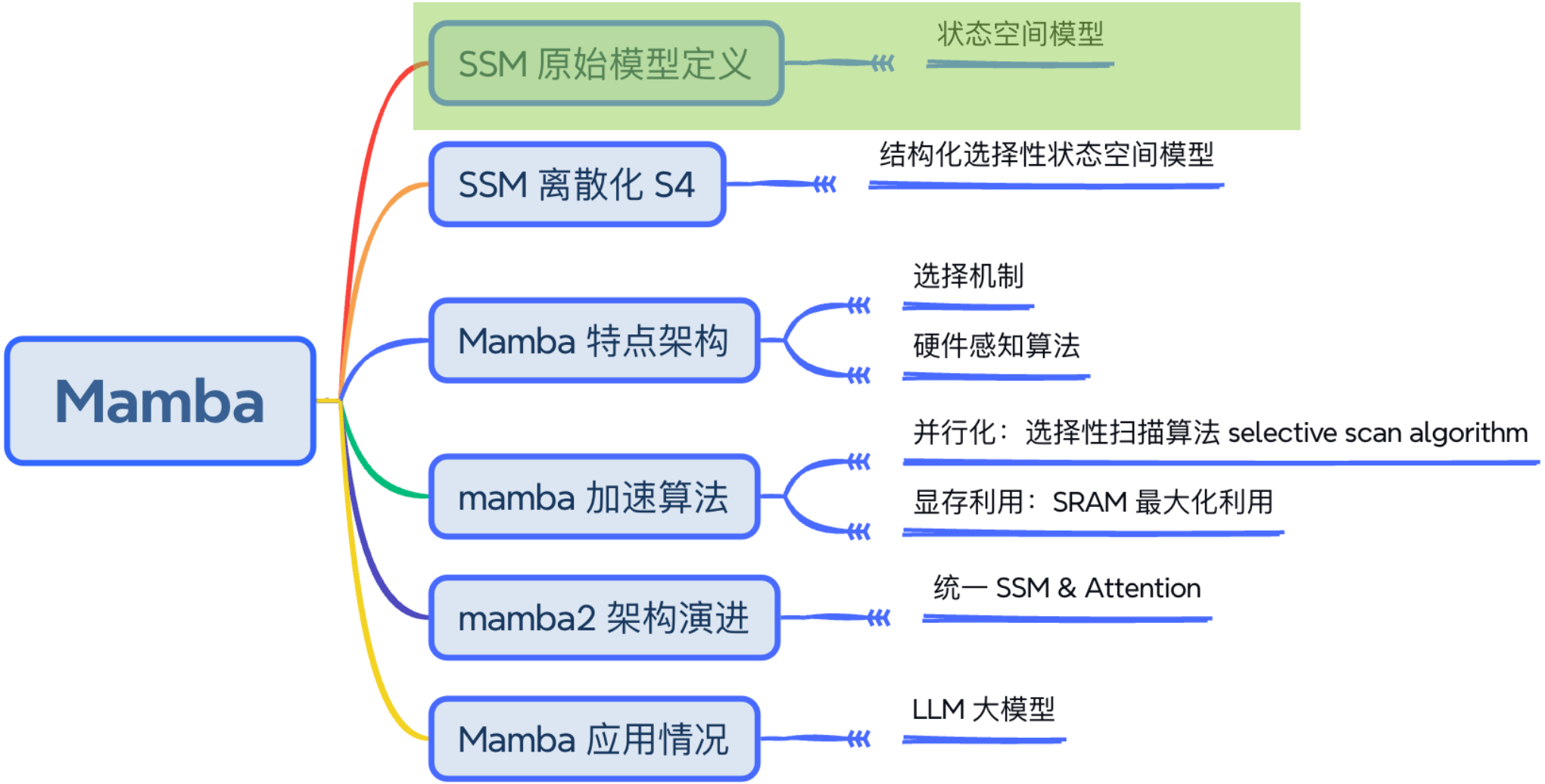
Mamba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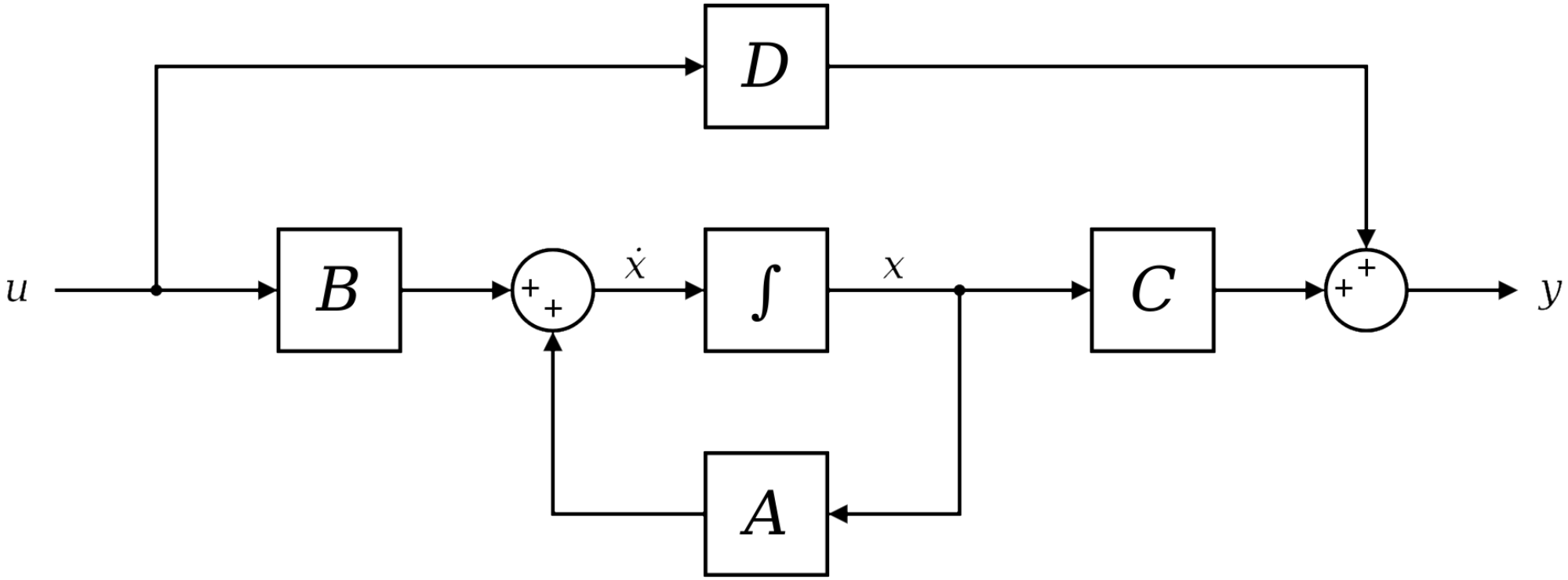
SSM

- Intelligent Control Systems: An Introduction with Examples
- State-space representation → State Space Model



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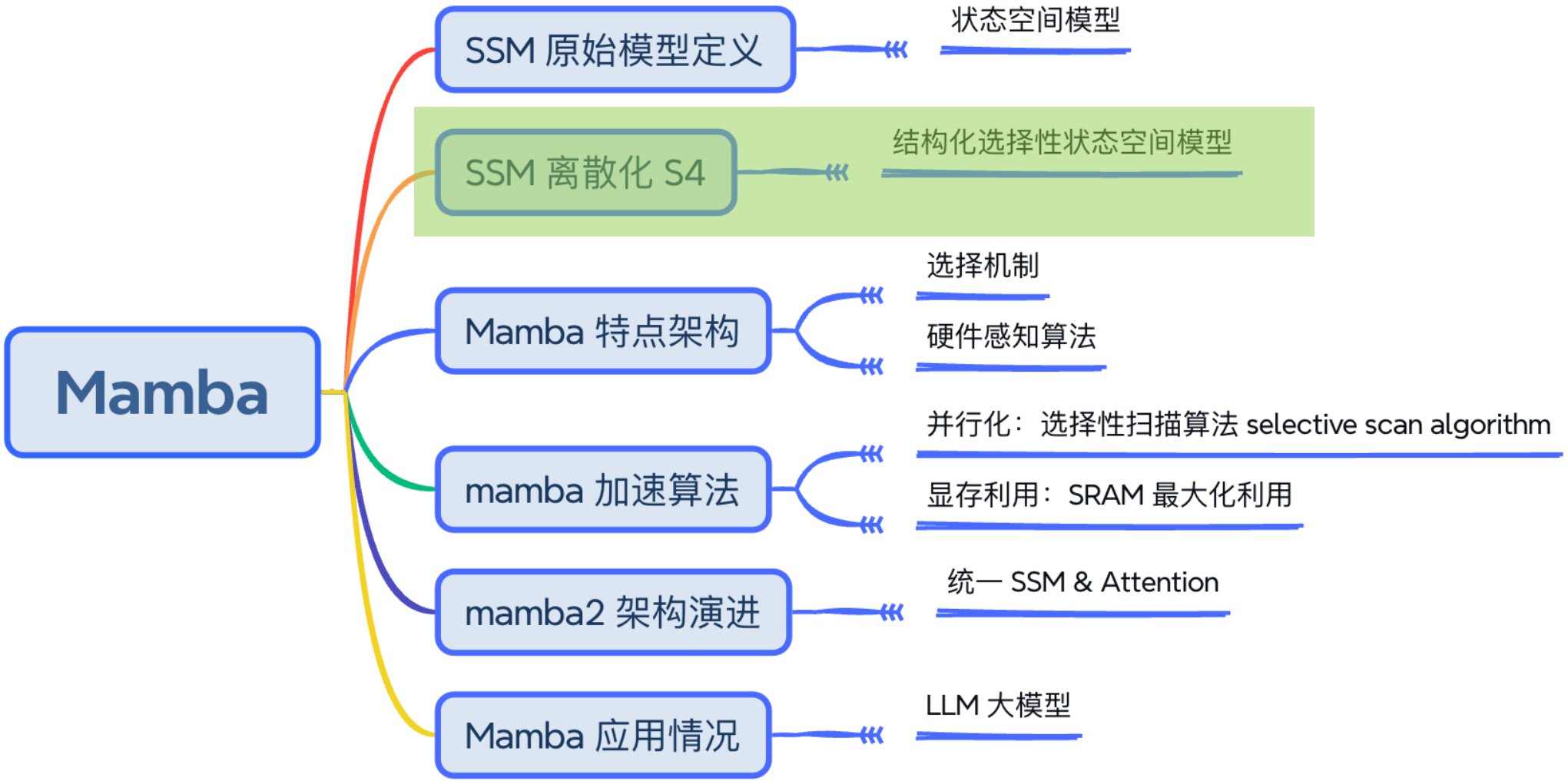
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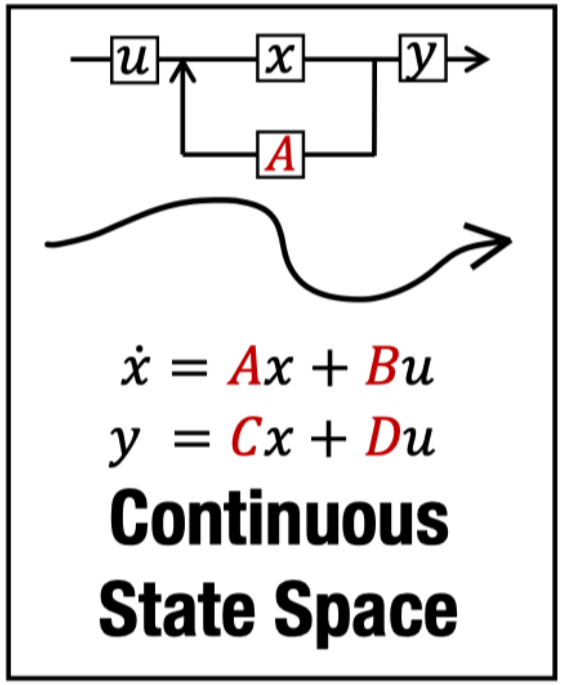
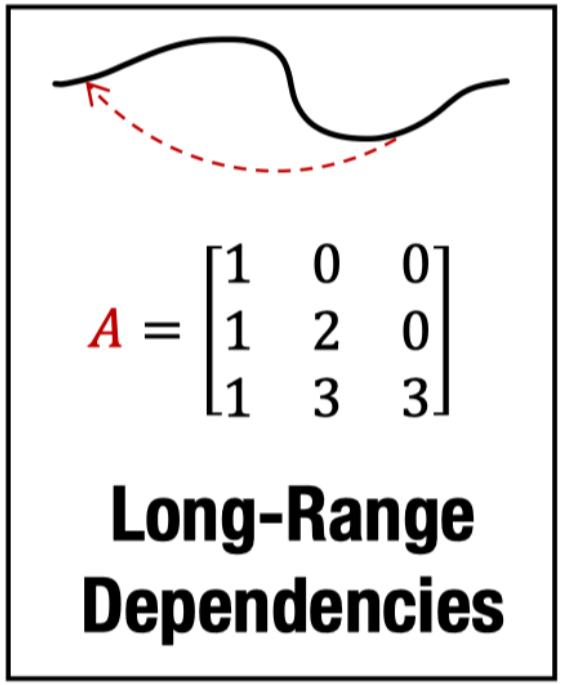
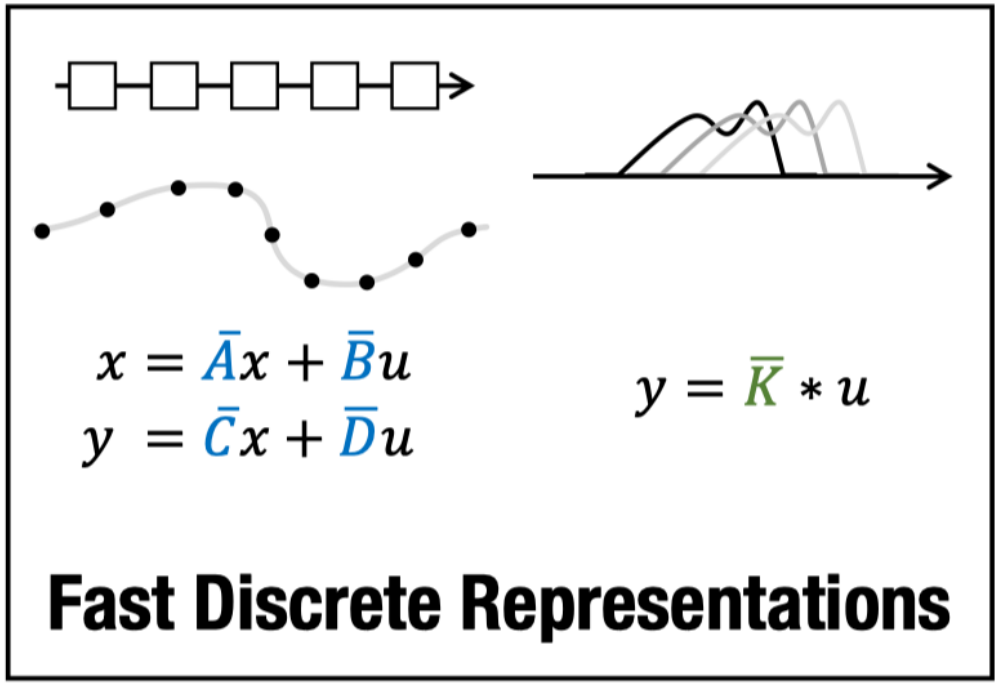
S4

- Paper: Efficiently Modeling Long **S**equences with **S**tructured **S**tate **S**paces
- aka. Structured State Space sequence model (S4)







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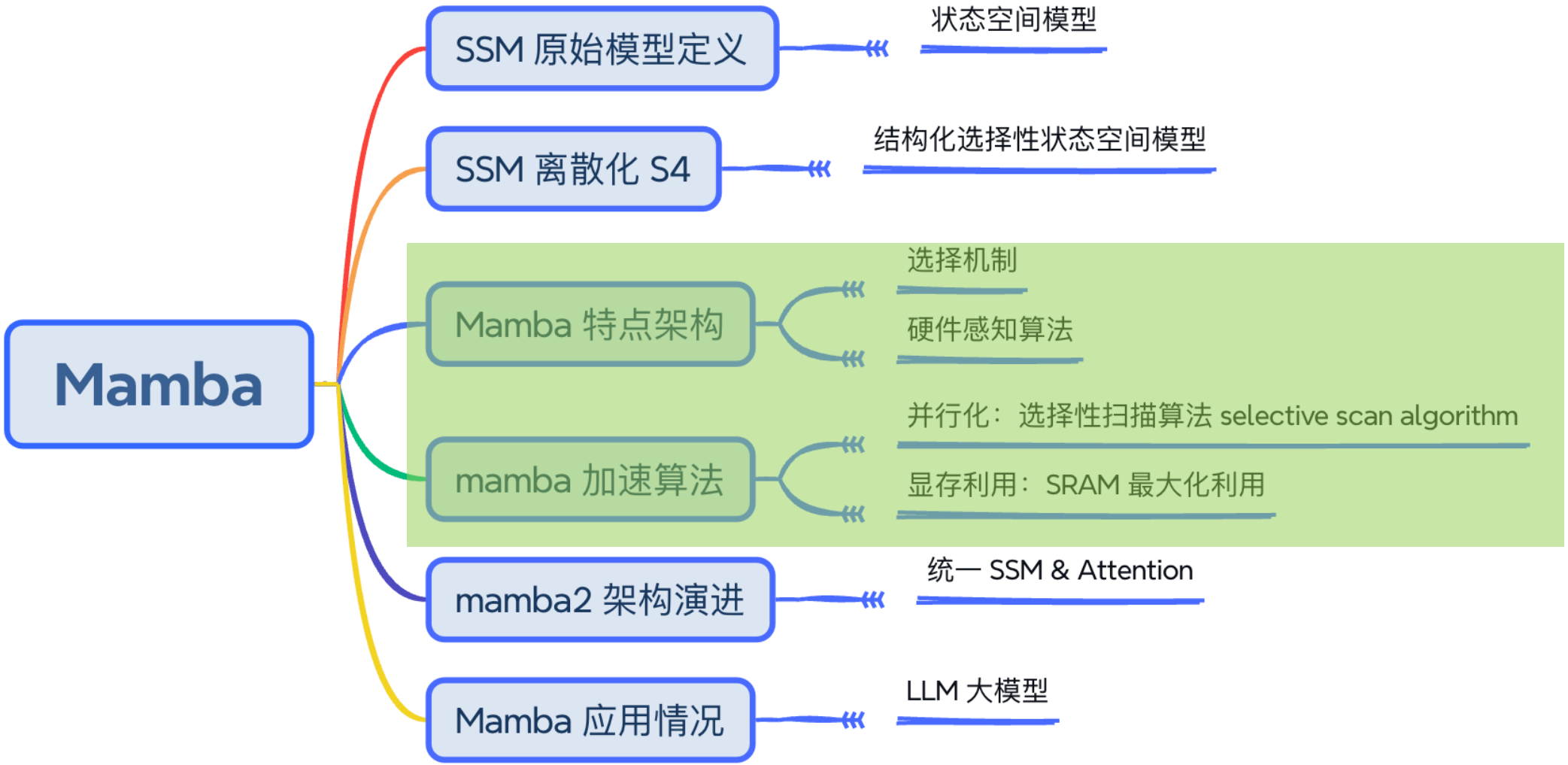
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mamba

Mamba: Linear-Time Sequence Modeling with Selective State Spaces

Albert Gu*[1] and Tri Dao*[2]

[1]Machine Learning Department, Carnegie Mellon University

[2]Department of Computer Science, Princeton University
agu@cs.cmu.edu, tri@tridao.me

FlashAttention: Fast and Memory-Efficient Exact Attention with IO-Awareness

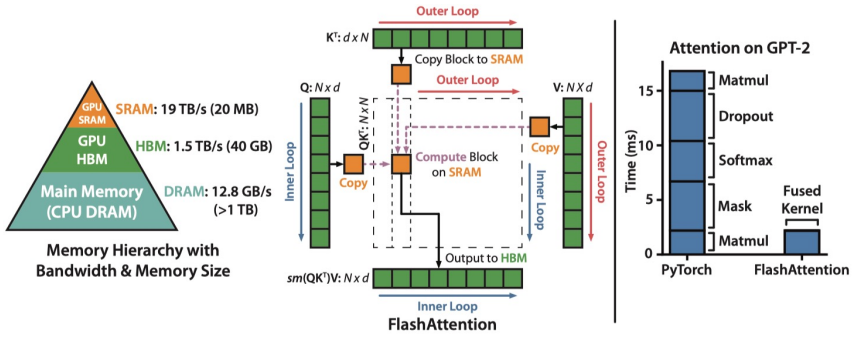
Tri Dao†, Daniel Y. Fu†, Stefano Ermon†, Atri Rudra‡, and Christopher Ré†

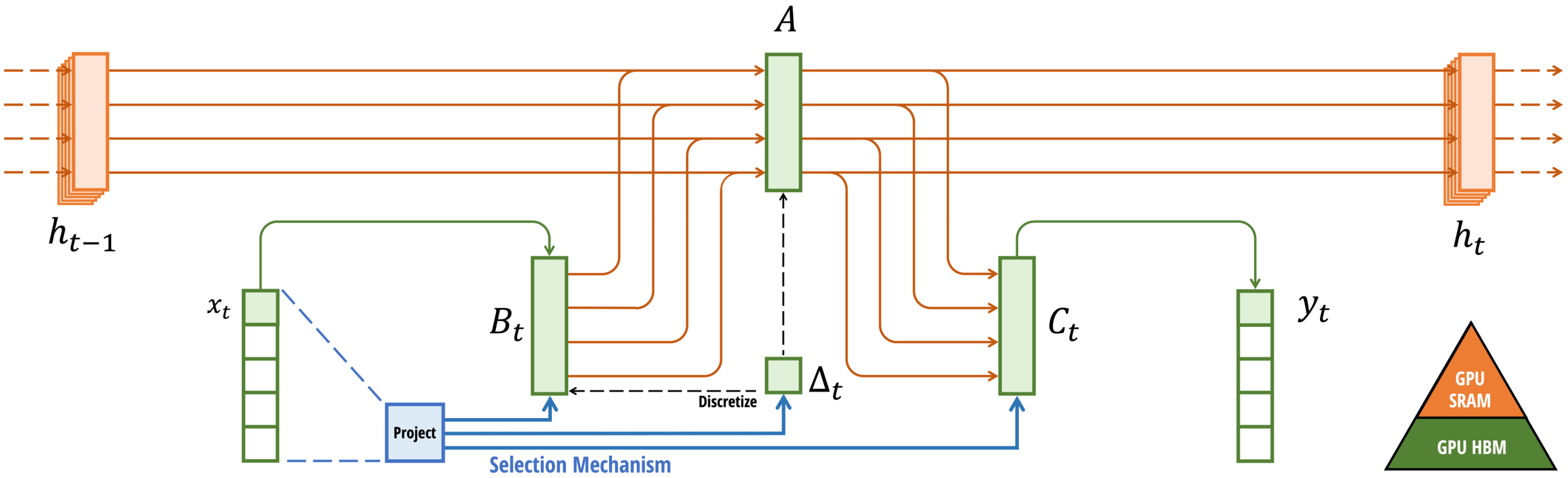
†Department of Computer Science, Stanford University
‡Department of Computer Science and Engineering, University at Buffalo, SUNY
{trid,danfu}@cs.stanford.edu, ermon@stanford.edu, atri@buffalo.edu,
chrismre@cs.stanford.edu

mamba

Selective State Space Model

with Hardware-aware State Expansion





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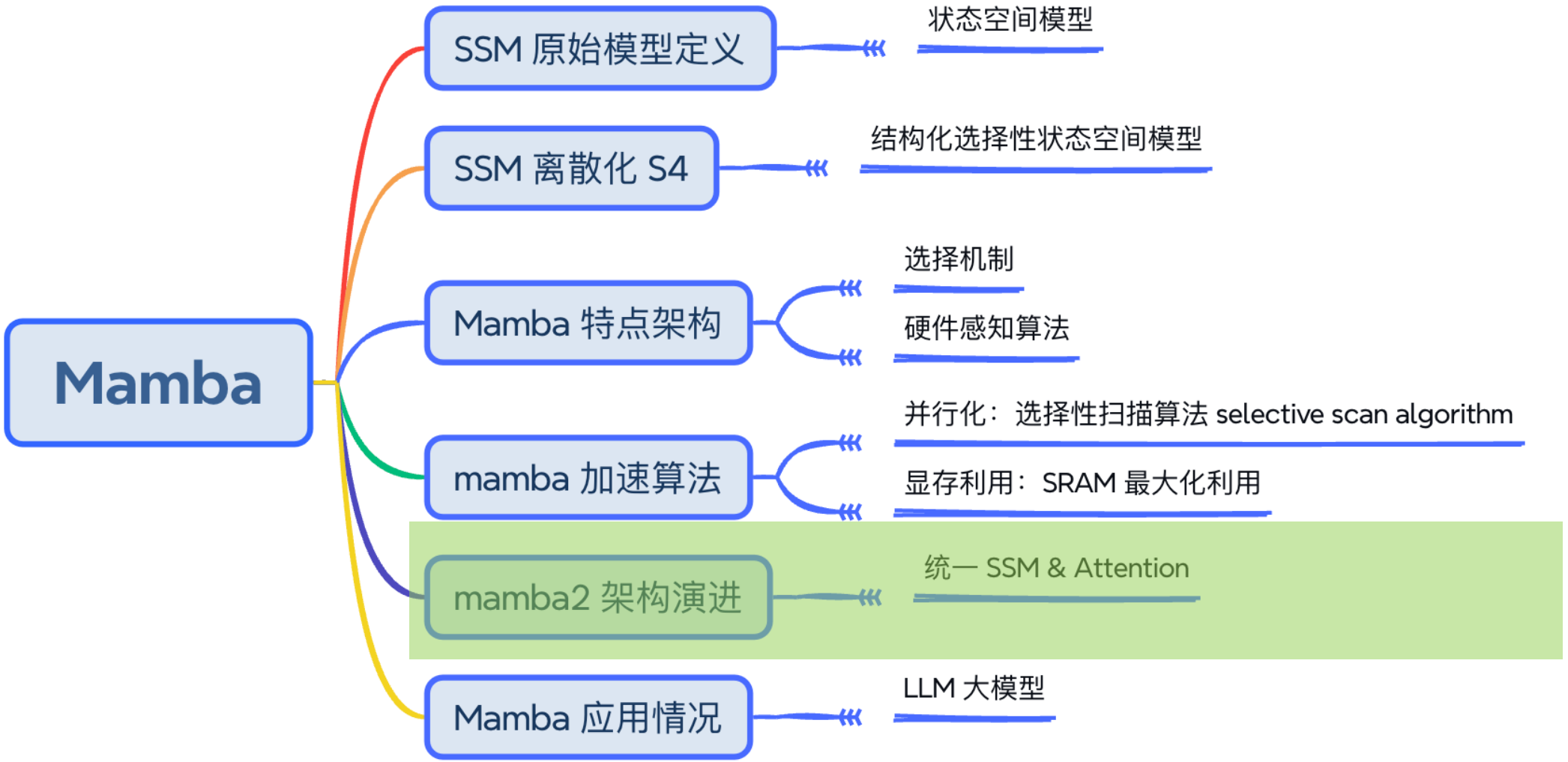
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mamba2

Transformers are SSMs: Generalized Models and Efficient Algorithms Through Structured State Space Duality

Tri Dao*[1] and Albert Gu*[2]

[1]Department of Computer Science, Princeton University

[2]Machine Learning Department, Carnegie Mellon University

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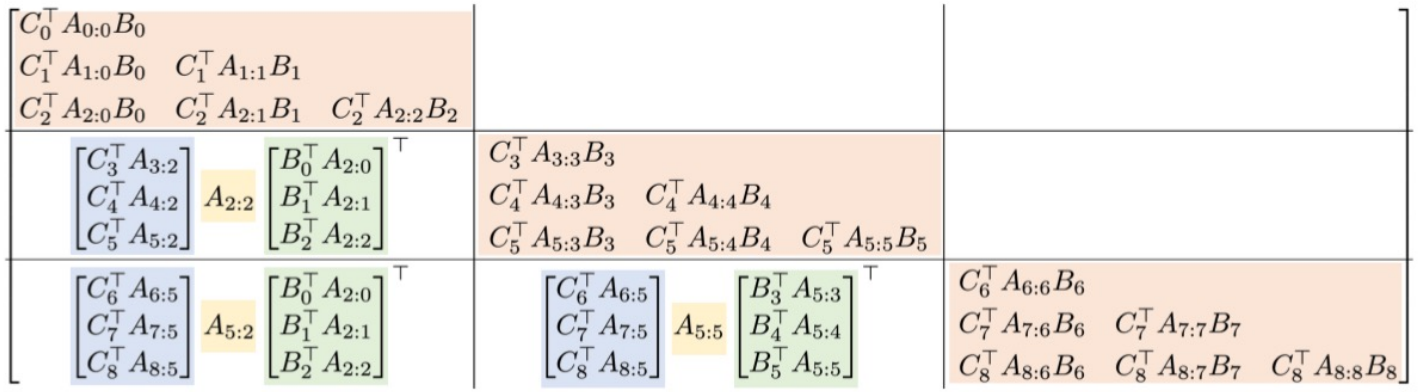
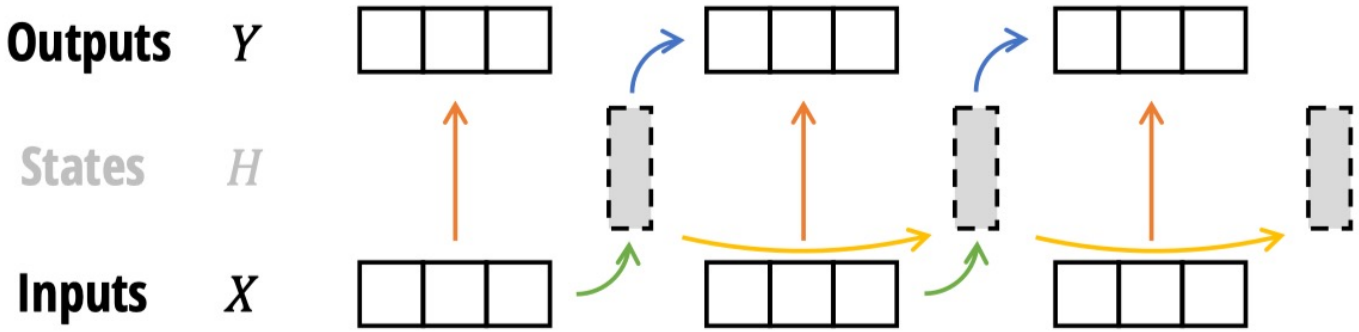
mamba2





Semiseparable Matrix M

Block Decomposition

- Diagonal Block: Input → Output
- Low-Rank Block: Input → State
- Low-Rank Block: State → State
- Low-Rank Block: State → Output

Reference 参考&引用

1. https://srush.github.io/annotated-s4/
2. https://huggingface.co/blog/lbourdois/get-on-the-ssm-train
3. https://en.wikipedia.org/wiki/State-space_representation
4. https://arxiv.org/abs/2405.21060
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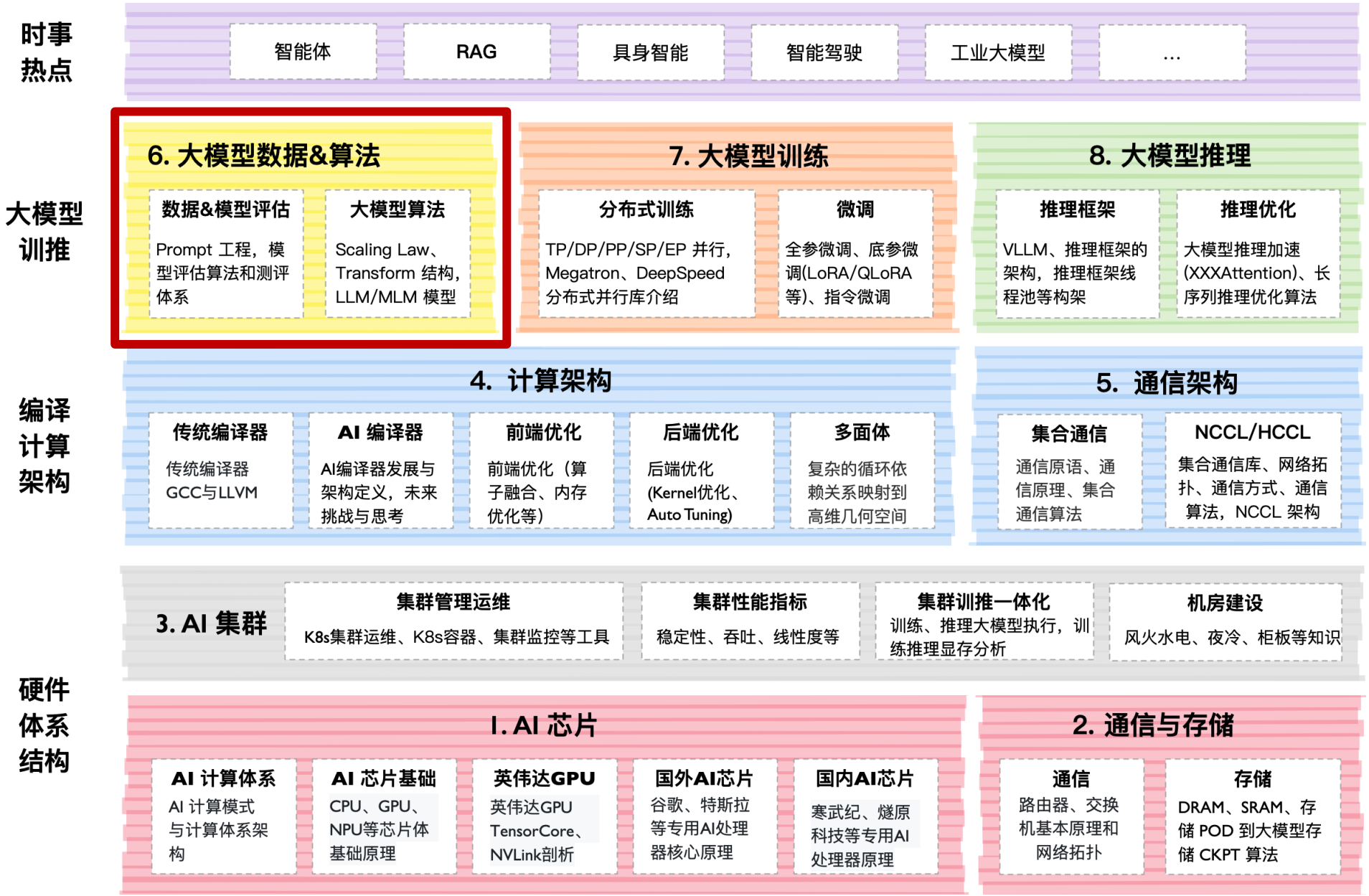
03

小结与思考


时事热点
智能体
RAG
具身智能
智能驾驶
工业大模型
...
大模型训推
6. 大模型数据&算法
数据&模型评估
Prompt 工程，模型评估算法和测评体系
大模型算法
Scaling Law、Transform 结构，LLM/MLM 模型
7. 大模型训练
分布式训练
TP/DP/PP/SP/EP 并行，Megatron、DeepSpeed 分布式并行库介绍
微调
全参微调、底参微调(LoRA/QLoRA 等)、指令微调
8. 大模型推理
推理框架
VLLM、推理框架的架构，推理框架线程池等构架
推理优化
大模型推理加速(XXXAttention)、长序列推理优化算法
编译计算架构
4. 计算架构
传统编译器
传统编译器 GCC与LLVM
AI 编译器
AI编译器发展与架构定义，未来挑战与思考
前端优化
前端优化（算子融合、内存优化等）
后端优化
后端优化(Kernel优化、Auto Tuning)
多面体
复杂的循环依赖关系映射到高维几何空间
5. 通信架构
集合通信
通信原语、通信原理、集合通信算法
NCCL/HCCL
集合通信库、网络拓扑、通信方式、通信算法，NCCL 架构
硬件体系结构
3. AI 集群
集群管理运维
K8s集群运维、K8s容器、集群监控等工具
集群性能指标
稳定性、吞吐、线性度等
集群训推一体化
训练、推理大模型执行，训练推理显存分析
机房建设
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英伟达GPU
英伟达GPU TensorCore、NVLink剖析
国外AI芯片
谷歌、特斯拉等专用AI处理器核心原理
国内AI芯片
寒武纪、燧原科技等专用AI处理器原理
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通信
路由器、交换机基本原理和网络拓扑
存储
DRAM、SRAM、存储 POD 到大模型存储 CKPT 算法

Thank you

把AI系统带入每个开发者、每个家庭、每个组织，构建万物互联的智能世界

Bring AI System to every person, home and organization for a fully connected, intelligent world.

ZOMI

Course chenzomi12.github.io

GitHub github.com/chenzomi12/DeepLearningSystem