PrefixSmart: Enhancing Large Language Model Efficiency through Advanced Prompt Management

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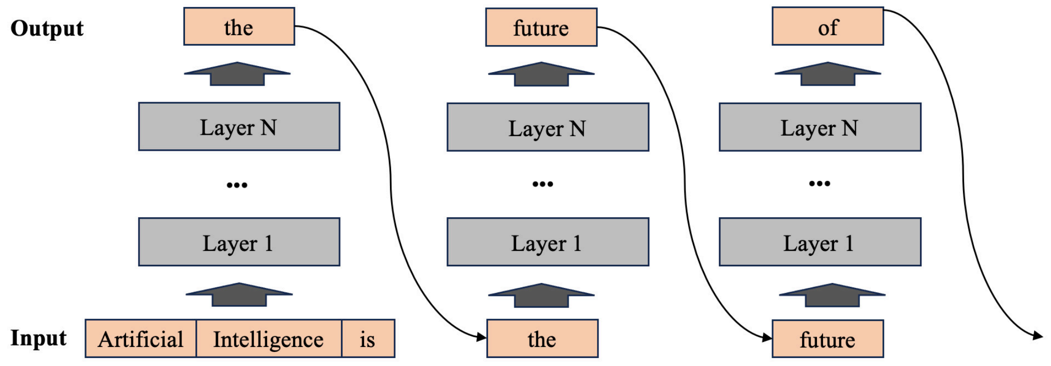
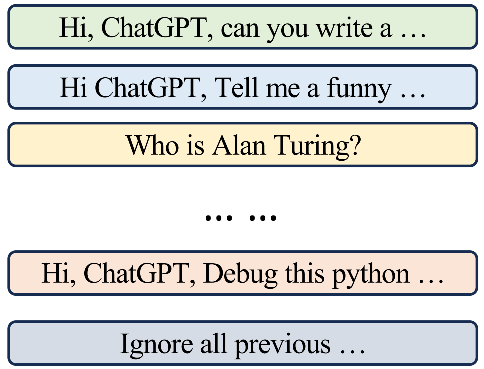
Intruduction of LLM and Motivation

Introductions of LLM Inference

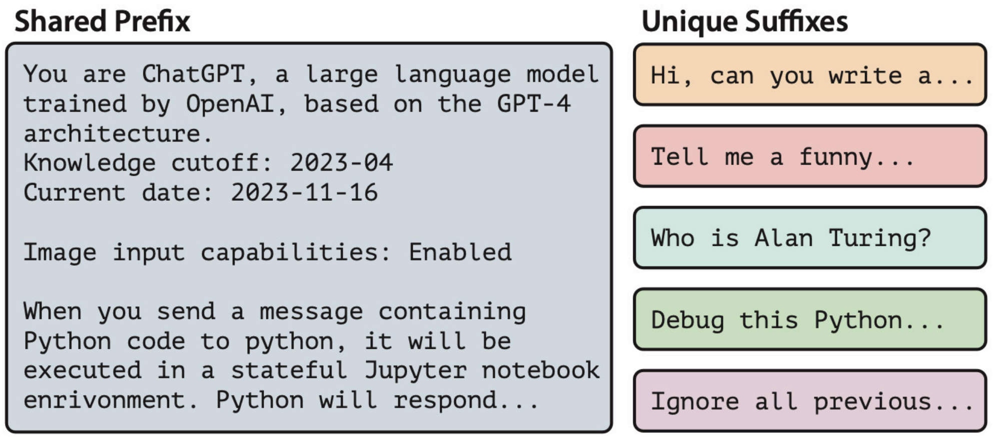
- Two stages:
  - Prefill: first iteration, compute all input tokens in a single pass
  - Decode: utilize previous generated token as input
- Regressive generation
- Use Batches of sequences to improve GPU utilization.




Hi, ChatGPT, can you write a …
Hi ChatGPT, Tell me a funny …
Who is Alan Turing?
… …
Hi, ChatGPT, Debug this python …
Ignore all previous …

Motivation of PrefixSmart

- All the tokens within a batch of requests is processed in prefill stage, even with duplicate tokens.
- In some scenarios, there exists similar prefix tokens, such as few-shot aibot applications.
- These common prefix tokens can only be execute once and shared by all the requests.

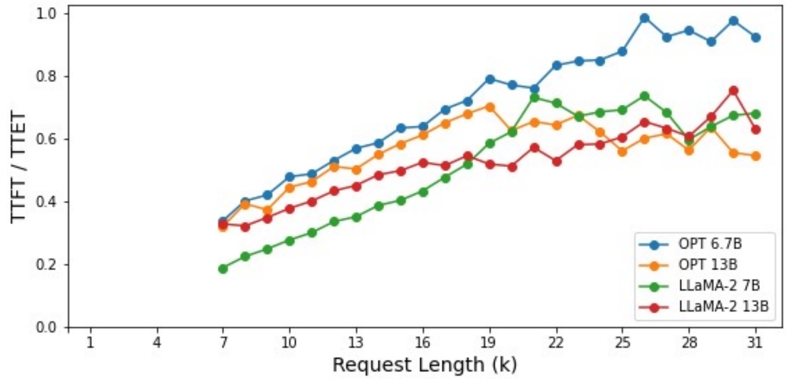


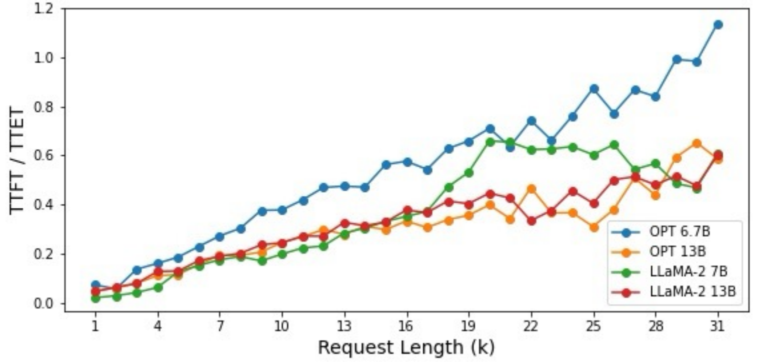
```
You are ChatGPT, a large language model
trained by OpenAI, based on the GPT-4
architecture.
Knowledge cutoff: 2023-04
Current date: 2023-11-16

Image input capabilities: Enabled

When you send a message containing
Python code to python, it will be
executed in a stateful Jupyter notebook
enrivonment. Python will respond...
```

```
Hi, can you write a...
Tell me a funny...
Who is Alan Turing?
Debug this Python...
Ignore all previous...
```

Prefill Latency vs End-to-End Latency

- The computational overhead during the prefill stage increases with the length of the prompts





Challenges of PrefixSmart

- How to detect the common prefix tokens efficiently.
    - Get shared prefix tokens
    - Group the requests with similar common prefix tokens.
- How to deal the interference from unequal-length suffixes
    - The prefill latency of different length prompt is different.
- Strategic offloading to CPUs
    - GPU memory is limited, the preemption will happen when GPU memory is not enough.
    - Use CPU rather than waiting for GPU resources.

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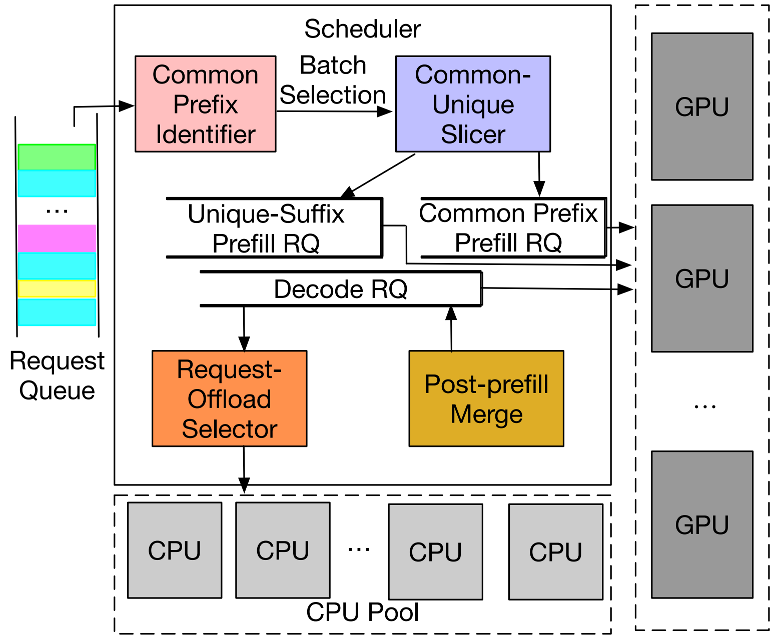
Design Details of PrefixSmart

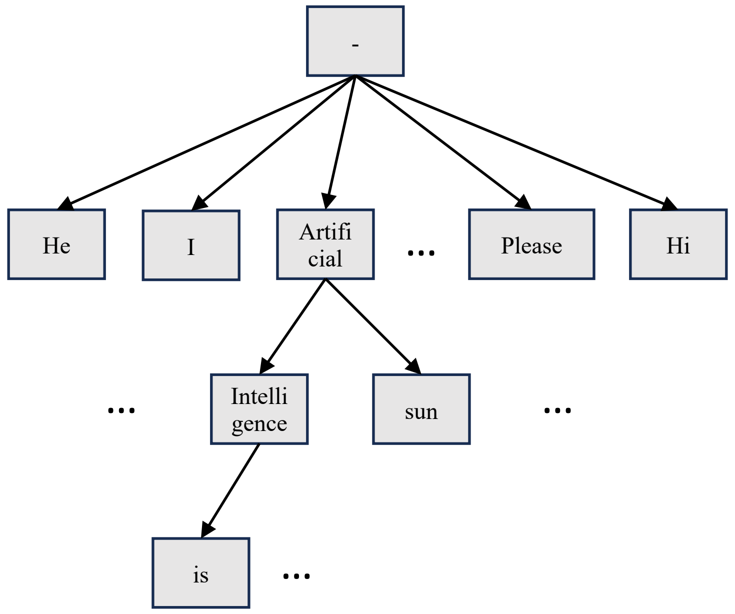
Overview of PrefixSmart

- Common-prefix Identifier
- Common-Unique Slicer
- Post-prefill merger
- Request-offload Selector



Common-prefix Identifier

- Efficiently detect shared prefixes in a large number of input prompts.
- Adopting a trie tree approach called radix tree for detecting shared prefixes within vast numbers of incoming requests.
- Prefix Radix Tree
  - Traditional trie tree can become unwieldy with deep and wide branches.
  - Compacting common phrases and frequently used word.
- Dynamic Pruning Strategy
  - Dividing the prefix tokens into ”Hot” and ”Cold” based on the frequency of them.
  - The “Cold” prefixes are actively pruned by the system.



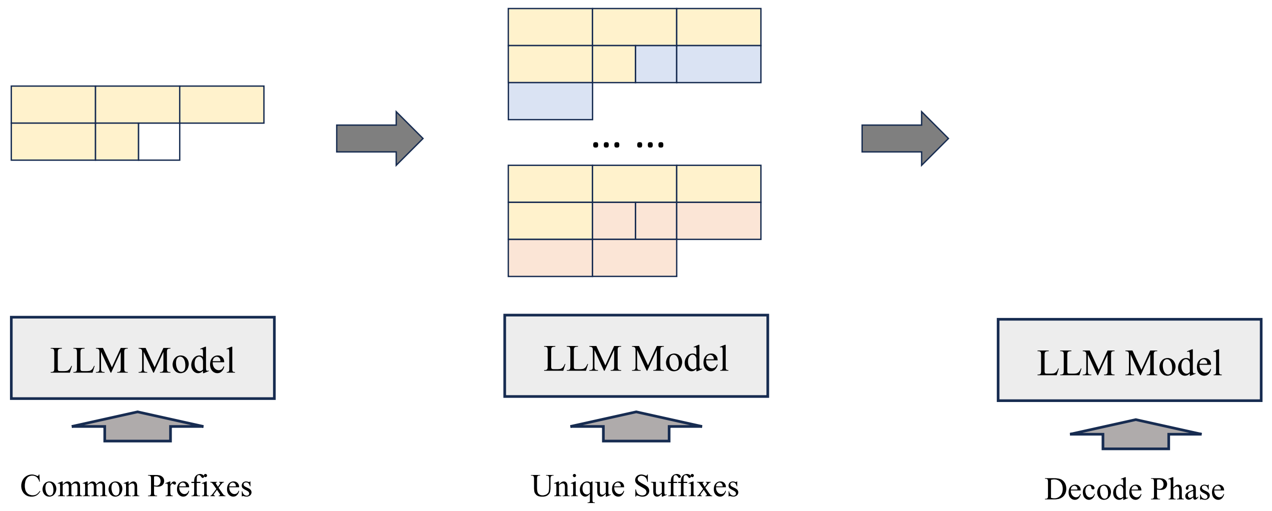
Common-Unique Slicer

- Intelligently segments prompts into shared prefix and unique suffix components.
  - Shared Prefix Trunk: Initial tokens shared across multiple prompts, allowing for single-time computation and reuse.
  - Unique Suffix Trunks: Distinct suffixes requiring individual processing for each prompt

- The shared prefix trunk and unique suffix trunks are assigned to different iterations of LLM inference.

Post-prefill Merger

- Integrates processed shared prefixes and unique suffixes into a coherent final output.
- Common-prefix Slicer: Dividing prompts into manageable parts
- Storage the KV cache through PagedAttention method



Request-offload Selector

- Offloading ‘Cold’ or less computation-intensive tasks to CPU and Host Memory.
- Frees GPU resources for more critical and ‘Hot’ taks, especially when GPU resources is unavailuable.
- The related KV cache should be offloaded.

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Discussion and Future Works

Discussion and Future Works

- PrefixSmart improve the resource efficiency by addressing computation redundancies in the prefill stage.
- Future Works:
  - Optimization of Long-Context Prompt Handling
    - Use lightweight neural network model
    - Segment long-context prompts into smaller
  - Refinement of Prompt Slicing and Scheduling Algorithms

Thanks