ggml

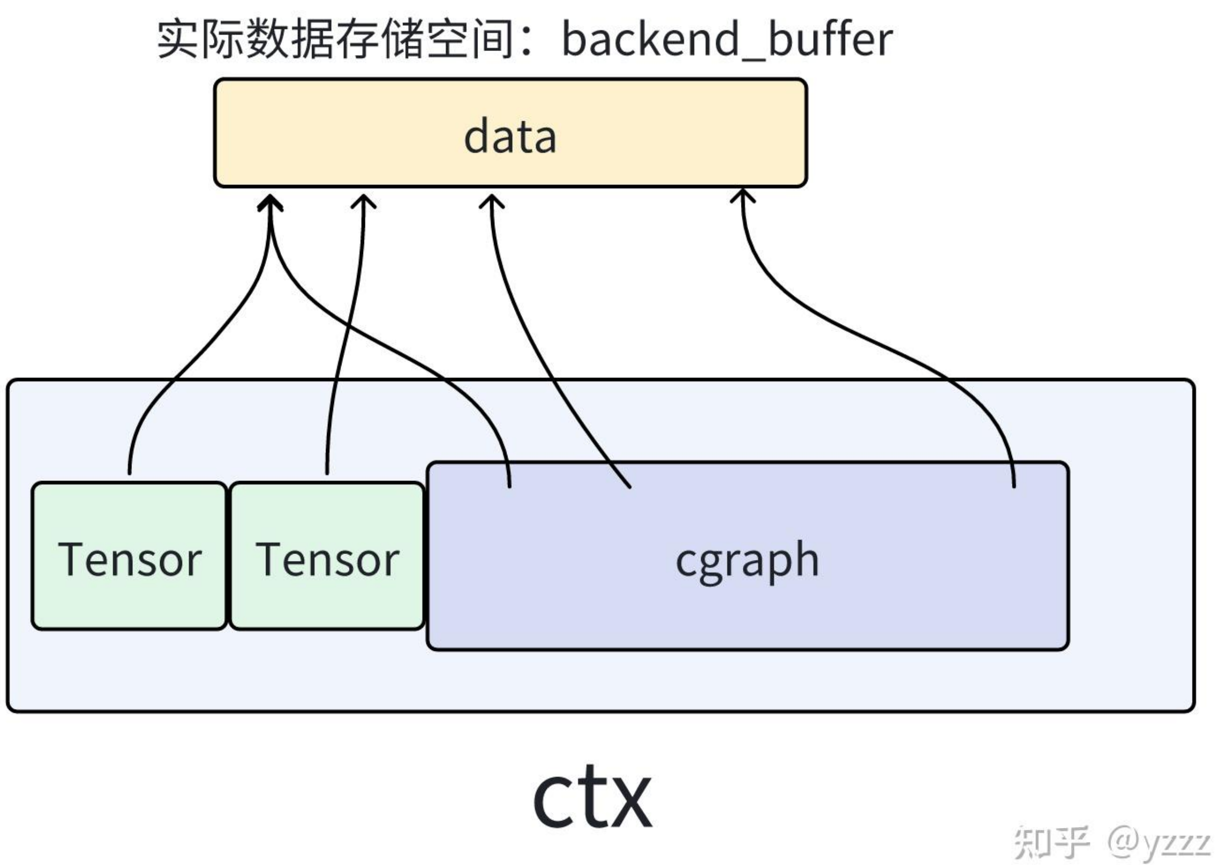
ggml是一个用 C 和 C++ 编写、专注于 Transformer 架构模型推理的机器学习库，ggml相当于c++版的pytroch。llama.cpp底层推理采用该库。 可以理解成它主要干了这个事`result = torch.matmul(matrix1, matrix2.T)`

关键概念：

- ggml_context: 一个装载各类对象 (如张量、计算图、其他数据) 的“容器”。

  对于ggml框架来说，无论要做什么（建立modle模型、建立计算图、还是创建承载计算结果的result）都需要先创建一个context作为容器，并将创建的结构体保存在context里（不包括实际数据本身，数据通过结构体里的指针索引）。实际数据的存储位置是由sched调度器与backend buffer后端缓冲所管理存放的

  所以在后续的计算中，我们只需要拿到ctx，就能拿到所有的信息列表，然后经过查找，就可以得到实际数据的存储指针、数据类型等信息。



- ggml_cgraph: 计算图的表示，可以理解为将要传给后端的“计算执行顺序”。
- ggml_tensor：ggml版的tensor表示，与pytorch类似，数据存储在data指针变量里;op保存在op指针里
- ggml_backend_t // the backend to perform the computation (CPU, CUDA, METAL)
- ggml_backend_buffer_t buffer; // the backend buffer to storage the tensors data

  在ggml框架中，一切数据（context、dataset、tensor...）都应该被存放在buffer中。之所以要用buffer进行集成，是为了便于实现多种后端（CPU、GPU）内存的统一管理。buffer是实现不同类型数据在多种

类型后端上进行统一的接口对象。

ggml_backend_buffer_t表示通过应后端backend通过分配的内存空间。需要注意的是，一个缓存可以存储多个张量数据。

要在CPU上完成上述矩阵乘法，步骤如下：

- 分配一个 ggml_context 对象来存储张量数据
- 分配张量并赋值
- 为矩阵乘法运算创建一个 ggml_cgraph
- 执行计算
- 获取计算结果
- 释放内存并退出

▶ Details

code

```
#include "ggml.h"
#include "ggml-cpu.h"
#include <string.h>
#include <stdio.h>

int main(void) {
    // initialize data of matrices to perform matrix multiplication
    const int rows_A = 4, cols_A = 2;
    float matrix_A[rows_A * cols_A] = {
        2, 8,
        5, 1,
        4, 2,
        8, 6
    };
    const int rows_B = 3, cols_B = 2;
    float matrix_B[rows_B * cols_B] = {
        10, 5,
        9, 9,
        5, 4
    };

    // 1. Allocate `ggml_context` to store tensor data
    // Calculate the size needed to allocate
    size_t ctx_size = 0;
    ctx_size += rows_A * cols_A * ggml_type_size(GGML_TYPE_F32); // tensor a
    ctx_size += rows_B * cols_B * ggml_type_size(GGML_TYPE_F32); // tensor b
    ctx_size += rows_A * rows_B * ggml_type_size(GGML_TYPE_F32); // result
    ctx_size += 3 * ggml_tensor_overhead(); // metadata for 3 tensors
    ctx_size += ggml_graph_overhead(); // compute graph
    ctx_size += 1024; // some overhead (exact calculation omitted for simplicity)

    // Allocate `ggml_context` to store tensor data
```

```
    struct ggml_init_params params = {
        /*.mem_size =*/ ctx_size,
        /*.mem_buffer =*/ NULL,
        /*.no_alloc =*/ false,
    };
    struct ggml_context * ctx = ggml_init(params);

    // 2. Create tensors and set data
    struct ggml_tensor * tensor_a = ggml_new_tensor_2d(ctx, GGML_TYPE_F32, cols_A, rows_A);
    struct ggml_tensor * tensor_b = ggml_new_tensor_2d(ctx, GGML_TYPE_F32, cols_B, rows_B);
    memcpy(tensor_a->data, matrix_A, ggml_nbytes(tensor_a));
    memcpy(tensor_b->data, matrix_B, ggml_nbytes(tensor_b));


    // 3. Create a `ggml_cgraph` for mul_mat operation
    struct ggml_cgraph * gf = ggml_new_graph(ctx);

    // result = a*b^T
    // Pay attention: ggml_mul_mat(A, B) ==> B will be transposed internally
    // the result is transposed
    struct ggml_tensor * result = ggml_mul_mat(ctx, tensor_a, tensor_b);

    // Mark the "result" tensor to be computed
    ggml_build_forward_expand(gf, result);

    // 4. Run the computation
    int n_threads = 1; // Optional: number of threads to perform some operations with multi-threading
    ggml_graph_compute_with_ctx(ctx, gf, n_threads);

    // 5. Retrieve results (output tensors)
    float * result_data = (float *) result->data;
    printf("mul mat (%d x %d) (transposed result):\n[", (int) result->ne[0], (int) result->ne[1]);
    for (int j = 0; j < result->ne[1]/* rows */; j++) {
        if (j > 0) {
            printf("\n");
        }

        for (int i = 0; i < result->ne[0]/* cols */; i++) {
            printf(" %.2f", result_data[j * result->ne[0] + i]);
        }
    }
    printf(" ]\n");

    // 6. Free memory and exit
    ggml_free(ctx);
    return 0;
}
```

对于gpu上的执行该矩阵乘法：https://github.com/ggerganov/ggml/blob/6c71d5a071d842118fb04c03c4b15116dff09621/examples/simple/simple-backend.cpp

一个好的示例mnist： https://github.com/ggml-org/ggml/blob/master/examples/mnist/README.md

gguf格式

gguf特性：

- 方便添加新信息到模型中
- mmap兼容，能够直接将文件映射到内存中
- 量化兼容
- key-value structure netadata

图示：

增加、修改模型的metadata:

- https://github.com/ggml-org/llama.cpp/blob/master/gguf-py/gguf/scripts/gguf_set_metadata.py
- https://github.com/ggml-org/llama.cpp/blob/master/gguf-py/gguf/scripts/gguf_new_metadata.py

doc:

- https://github.com/ggml-org/ggml/blob/master/docs/gguf.md
- https://huggingface.co/docs/hub/gguf

llama.cpp

参数转换

首先转换模型到gguf格式，参考 https://github.com/ggml-org/llama.cpp/blob/master/convert_hf_to_gguf.py#L4950

如 python convert_hf_to_gguf.py --outtype f16 --print-supported-models /mnt/models/opt-6.7b/

```
模型转换流程:
1. 从HF模型路径下加载config.json文件，读取模型配置
hparams = Model.load_hparams(dir_model)

2. 依据 hparams 的模型架构，得到llama.cpp定义的对应的模型，如：
GPTNeoXForCausalLM，并进行初始化
@Model.register("GPTNeoXForCausalLM")
class GPTNeoXModel(Model):

3. 然后调用llama.cpp定义的对应模型的接口，来完成模型转换
model_instance.set_gguf_parameters() # 将config.json中的参数配置写入到gguf文件的metadata中
model_instance.set_vocab()           # 进行词表转换，llama.cpp将词表数据也保存到了gguf文件中

这里底层的逻辑是在`GGUF-py`这个包里实现的`import gguf`
```

如果模型没有定义不支持（如opt就不支持）

1. 先添加模型名称，参考 https://github.com/ggml-org/llama.cpp/blob/master/convert_hf_to_gguf_update.py

如添加opt则{"name": "opt-6.7b","tokt": TOKENIZER_TYPE.BPE, "repo": "https://huggingface.co/facebook/opt-6.7b", }添加完后需要运行convert_hf_to_gguf_update

```
# Instructions:
#
# - Add a new model to the "models" list
# - Run the script with your huggingface token:
#
#   python3 convert_hf_to_gguf_update.py <huggingface_token>
#
# - The convert_hf_to_gguf.py script will have had its get_vocab_base_pre()
function updated
# - Update llama.cpp with the new pre-tokenizer if necessary
```

2. 还要在convert_hf_to_gguf.py添加该模型识别参数的类，类似`class GPTNeoXModel(Model)`

还没有太搞明白这里

运行

```
获取guuf格式模型后，编译llama.cpp，把cuda后端参数设置为on。

git clone https://github.com/ggerganov/llama.cpp

cpu版本：
cmake -B build
cmake --build build --config release

cuda版本：
cmake -B build -DLLAMA_CUDA=ON
cmake --build build --config release

如果要调试，记得，cuda版本，-j(multiple jobs 加速编译)：
cmake -B build -DLLAMA_CUDA=ON -DCMAKE_BUILD_TYPE=Debug
cmake --build build -j 8

编译完成后运行测试,一个简单的生成测试为例，<https://github.com/ggml-org/llama.cpp/blob/master/examples/simple/README.md>
CUDA_VISIBLE_DEVICES=0 ./build/bin/llama-simple -m /mnt/models/Llama-2-7b-hf/Llama-2-7B-hf-F16.gguf "Hello my name is"

成功后我们后面以最为通用的main方法进行解析：
CUDA_VISIBLE_DEVICES=0 ./build/bin/llama-cli -m /mnt/models/Llama-2-7b-hf/Llama-2-7B-hf-F16.gguf --prompt "Once upon a time" -n 128

注意 -ngl 这个参数，它代表：n_gpu_layers，这个参数默认是 0，所以如果不设置为一个比较大的数字，整个模型就会到 CPU 上面跑，即便你用了 cublas 等各种编译参数也是在 CPU 上。
```

代码分析

特点：先分配、后计算

这是llama.cpp与其他python推理框架思想上最大的区别之一。即在进行实际计算时，需要对过程中所有可能用到的数据、信息提前分配内存。从而在实际推理计算过程中，做到“0”内存分配（虽然使用mmap之后，在运行最初阶段。计算时仍然会触发read来加载缺页）。这样设计的原因是作者认为在运行过程中，malloc等内存分配函数的计算开销太大，而作为一款以边缘计算为主的推理框架，应该尽可能减少这种开销。

llama.cpp简要流程：

1. 通过c++构造qwen等model（调用算子来定义计算图），并将gguf中的数据加载到模型中
2. model本质上是一个计算图，采用逐个算子调用和异步执行，不存在算子融合等操作
3. 支持kv-cache/flash attention(默认不启用)
4. 支持各种后端

具体解析用ppt解析 llamacpp-powerinfer

powerinfer

使用

编译和llama.cpp差不多,目前编译会有很多warning,但是可以正常编译。

```
cuda:
cmake -S . -B build -DLLAMA_CUBLAS=ON
cmake --build build --config Release

cpu:
cmake -S . -B build
cmake --build build --config Release

cuda调试：
cmake -S . -B build -DLLAMA_CUBLAS=ON -DCMAKE_BUILD_TYPE=Debug
cmake --build build -j 8
```

模型权重格式有区别，*.powerinfer.gguf，包括**模型权重与预测器权重**

```
.
├── *.powerinfer.gguf (Unquantized PowerInfer model)
├── *.q4.powerinfer.gguf (INT4 quantized PowerInfer model, if available)
├── activation (Profiled activation statistics for fine-grained FFN
offloading)
│   ├── activation_x.pt (Profiled activation statistics for layer x)
│   └── ...
├── *.[q4].powerinfer.gguf.generated.gpuidx (Generated GPU index at runtime
for corresponding model)
```

转换模型参数from Original Model Weights + Predictor Weights至.powerinfer.gguf格式，参考

```
python convert.py --outfile ./ReluLLaMA-70B-PowerInfer-GGUF/llama-70b-
relu.powerinfer.gguf ./SparseLLM/ReluLLaMA-70B ./PowerInfer/ReluLLaMA-70B-
Predictor
```

推理参考

```
# ./build/bin/main -m /PATH/TO/MODEL -n $output_token_count -t $thread_num
-p $prompt --vram-budget $vram_gb
# CUDA_VISIBLE_DEVICES=0 ./build/bin/main -m /mnt/models/prosparse-llama-2-
7b-gguf/prosparse-llama-2-7b.gguf -n 64 -t 2 -p "write a story of sysu" --
vram-budget 4

batch推理参考 <https://github.com/SJTU-
IPADS/PowerInfer/blob/main/examples/batched/README.md>
```

- powerinfer同时也支持量化模型，使用方式相同；
- powerinfer暂时只支持ReLU/ReGLU/Squared，这三个激活函数，所以mistral, original llama,Qwen这些模型不支持,需要添加算子

代码解析

```
官方提供的已经整合weight和predictor gguf的信息

llama_model_loader: loaded meta data with 17 key-value pairs and 355
tensors from /mnt/models/prosparse-llama-2-7b-gguf/prosparse-llama-2-
7b.gguf (version GGUF V3 (latest))

每一层的模型参数：
llama_model_loader: - tensor    1:           blk.0.attn_norm.weight f32
[  4096,     1,     1,     1 ]
llama_model_loader: - tensor    2:          blk.0.ffn_down_t.weight f16
[  4096, 11008,     1,     1 ]
llama_model_loader: - tensor    3:            blk.0.ffn_gate.weight f16
[  4096, 11008,     1,     1 ]
llama_model_loader: - tensor    4:              blk.0.ffn_up.weight f16
[  4096, 11008,     1,     1 ]
llama_model_loader: - tensor    5:            blk.0.ffn_norm.weight f32
[  4096,     1,     1,     1 ]
llama_model_loader: - tensor    6:              blk.0.attn_k.weight f16
[  4096,  4096,     1,     1 ]
llama_model_loader: - tensor    7:         blk.0.attn_output.weight f16
[  4096,  4096,     1,     1 ]
llama_model_loader: - tensor    8:              blk.0.attn_q.weight f16
[  4096,  4096,     1,     1 ]
llama_model_loader: - tensor    9:              blk.0.attn_v.weight f16
[  4096,  4096,     1,     1 ]

每一层预测器的参数
llama_model_loader: - tensor  291:                 blk.0.fc1.weight f16
[  4096,  1024,     1,     1 ]
llama_model_loader: - tensor  292:                 blk.0.fc2.weight f16
[  1024, 11008,     1,     1 ]
```

这里只解析和llama.cpp不一样的地方

integrate sd into powerinfer

sd in llama.cpp

```
# basic greedy speculative decoding
# llama.cpp/examples/speculative-simple
# vllm exp : temperature=0.8, top_p=0.95

# -c size of the prompt context (default: %d, 0 = loaded from model)
# "--draft-max", "--draft", "--draft-n" number of tokens to draft for
```

```
speculative decoding
# --draft-min minimum number of draft tokens to use for speculative
decoding
# --draft-p-min minimum speculative decoding probability (greedy)
# --sampling-seq 采样方式
# -fa enable Flash Attention
CUDA_VISIBLE_DEVICES=0 build/bin/llama-speculative-simple \
    -m  /mnt/models/Llama-2-7b-hf/Llama-2-7B-hf-F16.gguf \
    -md /mnt/models/llama-160m/llama-160M-F16.gguf \
    -p "write a story of Little Red Riding Hood." \
    -c 0 -ngl 99 --color \
    --sampling-seq p --top-p 0.95 -fa --temp 0.8 \
    -ngld 99 --draft-max 16 --draft-min 5 --draft-p-min 0.9


#已解决：
#上面的代码会遇到一些问题：
#common_speculative_are_compatible: tgt: bos = 1 (1), eos = 2 (0)
#common_speculative_are_compatible: dft: bos = 0 (1), eos = 2 (0)
#所以我需要把这两个分词器特殊Id统一，我在想这个问题对训练预测器有没有影响（感觉没有）
#这里经过多次尝试只需要改config.json的token id就可以正常跑起来，但是不确定有什么影响
```

可以通过以下几个pr了解llama.cpp推测解码设计：

speculative : PoC for speeding-up inference via speculative sampling by ggerganov · Pull Request #2926 · ggml-org/llama.cpp

speculative : add tree-based sampling example by ggerganov · Pull Request #3624 · ggml-org/llama.cpp

Implement stochastic speculative sampling by mscheong01 · Pull Request #5625 · ggml-org/llama.cpp

据我所知，llama.cpp推测解码支持原始的greedy sampling, stochastic sampling, 以及tree-based sampling

- --temp=0 -> greedy
- --temp>0 -> stochastic
- --n_parallel(number of parallel sequences to decode) > 1 -> tree-based

需要注意的是，好像小模型的sample策略无法通过参数设置！可能需要手动设置

推测解码解析见ppt

integrate into powerinfer

- 遇到的一个问题llama160m prefill的时候第一个token（eos）没有输出，但是7b模型就不会,但是不影响结果
- 关于重复输出的问题，这应该与模型性能与采样的参数设置有关，有专门的penalty参数控制重复生成。
- 虽然可以稀疏得跑，但可能需要修改powerinfer算子，以适应矩阵乘
- 关于支持树状推测解码
- 目前小模型采样使用greedy
- 大模型目前使用的是greddy,参考原来代码加入stochastic

- error: failed to apply previously generated gpu split from '/mnt/models/prosparse-llama-2-7b-powerinfer/prosparse-llama-2-7b.gguf.generated.gpuidx

参考一下vllm的实现逻辑

```
"""Sampling parameters for text generation.

Overall, we follow the sampling parameters from the OpenAI text completion
API (https://platform.openai.com/docs/api-reference/completions/create).
In addition, we support beam search, which is not supported by OpenAI.

Args:
    n: Number of output sequences to return for the given prompt.
    best_of: Number of output sequences that are generated from the prompt.
        From these `best_of` sequences, the top `n` sequences are returned.
        `best_of` must be greater than or equal to `n`. By default,
        `best_of` is set to `n`.
    presence_penalty: Float that penalizes new tokens based on whether they
        appear in the generated text so far. Values > 0 encourage the model
        to use new tokens, while values < 0 encourage the model to repeat
        tokens.
    frequency_penalty: Float that penalizes new tokens based on their
        frequency in the generated text so far. Values > 0 encourage the
        model to use new tokens, while values < 0 encourage the model to
        repeat tokens.
    repetition_penalty: Float that penalizes new tokens based on whether
        they appear in the prompt and the generated text so far. Values > 1
        encourage the model to use new tokens, while values < 1 encourage
        the model to repeat tokens.
    temperature: Float that controls the randomness of the sampling. Lower
        values make the model more deterministic, while higher values make
        the model more random. Zero means greedy sampling.
    top_p: Float that controls the cumulative probability of the top tokens
        to consider. Must be in (0, 1]. Set to 1 to consider all tokens.
    top_k: Integer that controls the number of top tokens to consider. Set
        to -1 to consider all tokens.
    min_p: Float that represents the minimum probability for a token to be
        considered, relative to the probability of the most likely token.
        Must be in [0, 1]. Set to 0 to disable this.
    seed: Random seed to use for the generation.
    stop: List of strings that stop the generation when they are generated.
        The returned output will not contain the stop strings.
    stop_token_ids: List of tokens that stop the generation when they are
        generated. The returned output will contain the stop tokens unless
        the stop tokens are special tokens.
    bad_words: List of words that are not allowed to be generated.
        More precisely, only the last token of a corresponding
        token sequence is not allowed when the next generated token
        can complete the sequence.
    include_stop_str_in_output: Whether to include the stop strings in
        output text. Defaults to False.
```

```
    ignore_eos: Whether to ignore the EOS token and continue generating
        tokens after the EOS token is generated.
    max_tokens: Maximum number of tokens to generate per output sequence.
    min_tokens: Minimum number of tokens to generate per output sequence
        before EOS or stop_token_ids can be generated
    logprobs: Number of log probabilities to return per output token.
        When set to None, no probability is returned. If set to a non-None
        value, the result includes the log probabilities of the specified
        number of most likely tokens, as well as the chosen tokens.
        Note that the implementation follows the OpenAI API: The API will
        always return the log probability of the sampled token, so there
        may be up to `logprobs+1` elements in the response.
    prompt_logprobs: Number of log probabilities to return per prompt
token.
    detokenize: Whether to detokenize the output. Defaults to True.
    skip_special_tokens: Whether to skip special tokens in the output.
    spaces_between_special_tokens: Whether to add spaces between special
        tokens in the output.  Defaults to True.
    logits_processors: List of functions that modify logits based on
        previously generated tokens, and optionally prompt tokens as
        a first argument.
    truncate_prompt_tokens: If set to an integer k, will use only the last
k
        tokens from the prompt (i.e., left truncation). Defaults to None
        (i.e., no truncation).
    guided_decoding: If provided, the engine will construct a guided
        decoding logits processor from these parameters. Defaults to None.
    logit_bias: If provided, the engine will construct a logits processor
        that applies these logit biases. Defaults to None.
    allowed_token_ids: If provided, the engine will construct a logits
        processor which only retains scores for the given token ids.
        Defaults to None.
"""

prefill stage

    get prompt_token_ids=array('l', [2, 29631, 10, 527, 9, 410, 1211,
32280, 14604, 4]),
        output_token_ids=(280,), cumulative_logprob=0.0,
get_num_computed_tokens=10

WHILE not meet eos in decode stage

    call spculatice_decode_step_using_muti-step-worker

        assert for one loop for better show up

        call draft proposal with given num lookahead using top-1 proposer

            excute model

            sample_params is SamplingParams(n=1, presence_penalty=0.0,
frequency_penalty=0.0,
                repetition_penalty=1.0, temperature=0.8, top_p=0.95,
```

```
top_k=-1, min_p=0.0,
                seed=None, stop=[], stop_token_ids=[], bad_words=[],
include_stop_str_in_output=False,
                ignore_eos=False, max_tokens=1024, min_tokens=0,
logprobs=None, prompt_logprobs=None,
                skip_special_tokens=True,
spaces_between_special_tokens=True, truncate_prompt_tokens=None,
guided_decoding=None)

            return proposal_tokens = tensor([ 16,   5, 129,  86, 939]) and
proposal_probs

        call score_proposal with SequenceData and proposal_tokens using
mqa_score

            input is prompt_token_ids=[2, 29631, 10, 527, 9, 410, 1211,
32280, 14604, 4]
            input is new_output_token_ids=[280, 16, 5, 129, 86, 939]

            excute model

            sample_params is SamplingParams(n=1, presence_penalty=0.0,
frequency_penalty=0.0,
                repetition_penalty=1.0, temperature=0.8, top_p=0.95,
top_k=-1, min_p=0.0, seed=None,
                stop=[], stop_token_ids=[],d bad_words=[],
include_stop_str_in_output=False, ignore_eos=False,
                max_tokens=1024, min_tokens=0, logprobs=None,
prompt_logprobs=None, skip_special_tokens=True,
                spaces_between_special_tokens=True,
truncate_prompt_tokens=None, guided_decoding=None)

            get target_sampler_output=(outputs=[],
sampled_token_probs=torch.Size([6, 50272]),
                sampled_token_ids=torch.Size([6, 1]),
spec_decode_worker_metrics=None)
            get target_sampler_output.sampled_token_ids=tensor([[ 40,  10,
129, 169,  38, 655]])
            note 655 is bonus token

            return sampled_token_ids

        call verification with proposal_scores and proposal_tokens

            input is proposal_scores = tensor([[ 40,  10, 129, 169,  38,
655]], device='cuda:0')
            input is proposal_tokens = tensor([ 16, 5, 129, 86, 939]

            call modified rejection sampling on each sequence.

                call get_accepted
                """Create bool matrix over the proposed draft tokens. If
                True, then a token can be accepted, else it should be
                rejected.
```

```
                Given :math:`q(\hat{x}_{n+1}|x_1, \dots, x_n)`, the
probability of
                :math:`\hat{x}_{n+1}` given context :math:`x_1, \dots, x_n`
according
                to the target model, and :math:`p(\hat{x}_{n+1}|x_1, \dots,
x_n)`, the
                same conditional probability according to the draft model,
the token
                is accepted with probability:

                .. math::
                    \min\left(1, \frac{q(\hat{x}_{n+1}|x_1, \dots, x_n)}
                                   {p(\hat{x}_{n+1}|x_1, \dots,
x_n)}\right)

                This implementation does not apply causality. When using
the output,
                if a token is rejected, subsequent tokens should not be
used.

                Returns a bool tensor of shape [batch_size, k] specifying
which tokens
                are accepted.
                """

                call_get_recoverd
                """Create a probability distribution for each proposed
token which can
                be sampled if the proposed token is rejected.

                When this routine is applied sequentially, the true
distribution of the
                target model is recovered (within hardware numerics).

                The probability distribution used in this rejection case is
constructed
                as follows. Given :math:`q(x|x_1, \dots, x_n)`, the
probability of
                :math:`x` given context :math:`x_1, \dots, x_n` according
to the target
                model and :math:`p(x|x_1, \dots, x_n)`, the same
conditional probability
                according to the draft model:

                .. math::
                    x_{n+1} \sim (q(x|x_1, \dots, x_n) - p(x|x_1, \dots,
x_n))_+

                where :math:`(f(x))_+` is defined as:

                .. math::
                    (f(x))_+ = \frac{\max(0, f(x))}{\sum_x \max(0, f(x))}
```

```
                See https://github.com/vllm-project/vllm/pull/2336 for a
visualization
                of the draft, target, and recovered probability
distributions.

                Returns a tensor of shape [batch_size, k, vocab_size].

                Note: This batches operations on GPU and thus constructs
the recovered
                distribution for all tokens, even if they are accepted.
This causes
                division-by-zero errors, so we use
self._smallest_positive_value to
                avoid that. This introduces some drift to the distribution.
                """

                then call multinomial-sample and get recover token

            get accepted = tensor([[ True,  True,  True, False,
True]],device='cuda:0'),
            get recovered_token_ids = tensor([[ 169,  114,  144, 2949,
47]],device='cuda:0')
            (Token ids sampled from a recovered distribution, to be used
when a token is rejected.)

            return accepted_token_ids = tensor([[  16,    5,  129, 2949,
-1,   -1]],device='cuda:0')

ENDWHILE
```

参考

- https://www.bilibili.com/video/BV1Ez4y1w7fc 不错的视频解析llama.cpp
- https://www.bilibili.com/video/BV1N4wreWE8z 较为详细解析llama.cpp
- llama.cpp源码解析--CUDA流程版本 - CodeLearner的文章 - 知乎 https://zhuanlan.zhihu.com/p/665027154
- https://zhuanlan.zhihu.com/p/691347732
- https://zhuanlan.zhihu.com/p/25774381094
- https://huggingface.co/blog/zh/introduction-to-ggml
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- llama.cpp（持续更新） - 单单野草的文章 - 知乎 https://zhuanlan.zhihu.com/p/697880115
- 笔记：Llama.cpp 代码浅析（一）：并行机制与KVCache - 刀刀宁的文章 - 知乎 https://zhuanlan.zhihu.com/p/670515231
- 笔记：Llama.cpp 代码浅析（二）：数据结构与采样方法 - 刀刀宁的文章 - 知乎 https://zhuanlan.zhihu.com/p/671761052