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RKNN API For RKNPU User Guide

(Technology Department, Graphic Compute Platform Center)

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1 Overview

RKNN SDK provides programming interfaces for all chips platforms with RKNPU, which can help users deploy RKNN models from RKNN-Toolkit2 and accelerate the implementation of AI applications.

2 Supported Hardware Platforms

This document applies to the following hardware platforms:

RK3566, RK3568, RK3588, RK3588S, RV1103, RV1106

Note: RK356X is used to indicate RK3566/RK3568 in this document. RK3588 is used to indicate RK3588/RK3588S in this document.

3 Glossary

RKNN Model: It is the binary file running on the RKNPU, with the suffix .rknn.

Inference with board: It refer to use RKNN-Toolkit2 API interface to run the model. Actually, the model is running on the NPU on the development board.

HIDL: It denotes interface description language (IDL) to specify the interface between an android HAL and its users.

CTS: It is the Compatibility Test Suite from android automatic testing kit.

VTS: It is the Vendor Test Suite from android automatic testing kit.

DRM: It is the Direct Rendering Manager, a main stream of graph displaying framework on linux.

tensor: A multi-dimensional array of data.

fd: It is the file descriptor for representing the buffer.

NATIVE_LAYOUT: It refers to the native layout of NPU. In other words, it has the best performance when NPU is processing data with this memory layout.

i8 model: A quantized RKNN model which running by 8-bit signed integer data.

fp16 model: A non-quantized RKNN model which running by 16-bit half-float data.

4 Instructions

4.1 RKNN SDK Development Process

Before using the RKNN SDK, users first need to utilize the RKNN-Toolkit2 to convert the user's model to the RKNN model.

After getting the RKNN model file, users can choose using C interface to develop the application. The following chapters will explain how to develop applications via the RKNN SDK on RK356X/RK3588/RV1106/RV1103 platform.

4.2 RKNN Linux Platform Development Instructions

4.2.1 RKNN API Library For Linux

For the RK3566/RK3568, the SDK library file is librknnrt.so under the directory of <sdk>/rknpu2/runtime. As for the RV1106/RV1103, the SDK library file is librknnmrt.so under the directory of <sdk>/rknpu2/runtime.

4.2.2 Example Usage

The SDK provides MobileNet image classification, SSD object detection, YOLOv5 object detection demos. These demos are the reference for developers to develop applications based on the RKNN SDK. The demo is located at the path of <sdk>/rknpu2/examples. Let's take RK356X rknn_mobilenet_demo as an example to explain how to get started quickly.

1) Compile Demo Source Code

```
cd examples/rknn_mobilenet_demo
# set GCC_COMPILER in build-linux.sh to the correct compiler path
./build-linux_RK356X.sh
```

2) Deploy to the RK356X device

```
adb push install/rknn_mobilenet_demo_Linux /userdata/
```

3) Run Demo

```
adb shell
cd /userdata/rknn_mobilenet_demo_Linux/
export LD_LIBRARY_PATH=./lib
./rknn_mobilenet_demo model/RK356X/mobilenet_v1.rknn model/dog_224x224.jpg
```

4.3 RKNN Android Platform Development Instructions

4.3.1 RKNN API Library For Android

There are two ways to call the RKNN API on the Android platform

1) The application can link librknnrt.so directly

2) Application link to librknn_api_android.so implemented by HIDL on Android platform

For Android devices that need to pass the CTS/VTS test, you can use the RKNN API based on the Android platform HIDL implementation. If the device does not need to pass the CTS/VTS test, it is recommended to directly link and use librknnrt.so as this way can shorten the callingand linking processing of each interface to offer better performance.

The code for the RKNN API implemented using Android HIDL is located in the vendor/rockchip/hardware/interfaces/neuralnetworks directory of the RK356X Android system SDK. When the Android system is compiled, some NPU related libraries will be generated (for applications only need to link librknn_api_android.so), as shown below:

```
/vendor/lib/librknn_api_android.so
/vendor/lib/librknnhal_bridge.rockchip.so
/vendor/lib64/librknn_api_android.so
/vendor/lib64/librknnhal_bridge.rockchip.so
/vendor/lib64/rockchip.hardware.neuralnetworks@1.0.so
/vendor/lib64/rockchip.hardware.neuralnetworks@1.0-adapter-helper.so
/vendor/lib64/hw/rockchip.hardware.neuralnetworks@1.0-impl.so
/vendor/bin/hw/rockchip.hardware.neuralnetworks@1.0-service
```

Alternatively, user can use the following command to recompile and generate the above library separately.

```
mmm vendor/rockchip/hardware/interfaces/neuralnetworks/ -j8
```

4.3.2 Example Usage

The SDK currently provides examples of MobileNet image classification, SSD object detection , YOLOv5 object detection and Android APK demo with camera inputs . The demo code is located in the <sdk>/rknpu2/examples directory. Users can use NDK to compile the demo executed in the Android command line. Let's take RK356X rknn_mobilenet_demo as an example to explain how to use this demo on the Android platform:

1) Compile Demo Source Code

```
cd examples/rknn_mobilenet_demo
#set ANDROID_NDK_PATH under build-android.sh to the correct NDK path
./build-android_RK356X.sh
```

2) Deploy to the RK3566 device

```
adb push install/rknn_mobilenet_demo_Android /data/
```

3) Run Demo

```
adb shell
cd /data/rknn_mobilenet_demo_Andorid/
export LD_LIBRARY_PATH=./lib
./rknn_mobilenet_demo model/RK356X/mobilenet_v1.rknn model/dog_224x224.jpg
```

Note: The above demo uses the librknnrt.so by default. For developers who want to use

librknn_api_android.so, please refer to the README.md under the path of examples/librknn_api_android_demo/README.md.

4.4 RKNN C API

4.4.1 C API hardware platform support description

（1）RKNN C API hardware platform support：

	RKNN C API	RK356X	RK3588	RV1106/RV1103
1	rknn_init	√	√	√
2	rknn_set_core_mask	×	√	×
3	rknn_dup_context	√	√	×
4	rknn_destroy	√	√	√
5	rknn_query	√	√	√
6	rknn_inputs_set	√	√	×
7	rknn_run	√	√	√
8	rknn_wait	×	×	×
9	rknn_outputs_get	√	√	×
10	rknn_outputs_release	√	√	√
11	rknn_create_mem_from_mb_blk	×	×	×
12	rknn_create_mem_from_phys	√	√	√
13	rknn_create_mem_from_fd	√	√	√
14	rknn_create_mem	√	√	√
15	rknn_destroy_mem	√	√	√
16	rknn_set_weight_mem	√	√	√
17	rknn_set_internal_mem	√	√	√
18	rknn_set_io_mem	√	√	√

For more detailed instructions on RKNN C API，please refer to section 4.4.3 API Reference

（2）rknn_query params hardware platform support：

	rknn_query params	RK356X	RK3588	RV1106/RV1103
1	RKNN_QUERY_IN_OUT_NUM	√	√	√
2	RKNN_QUERY_INPUT_ATTR	√	√	√
3	RKNN_QUERY_OUTPUT_ATTR	√	√	√
4	RKNN_QUERY_PERF_DETAIL	√	√	×
5	RKNN_QUERY_PERF_RUN	√	√	×
6	RKNN_QUERY_SDK_VERSION	√	√	√
7	RKNN_QUERY_MEM_SIZE	√	√	√
8	RKNN_QUERY_CUSTOM_STRING	√	√	√
9	RKNN_QUERY_NATIVE_INPUT_ATTR	√	√	√
10	RKNN_QUERY_NATIVE_OUTPUT_ATTR	√	√	√
11	RKNN_QUERY_NATIVE_NC1HWC2_INPUT_ATTR	√	√	√
12	RKNN_QUERY_NATIVE_NC1HWC2_OUTPUT_ATTR	√	√	√
13	RKNN_QUERY_NATIVE_NHWC_INPUT_ATTR	√	√	√
14	RKNN_QUERY_NATIVE_NHWC_OUTPUT_ATTR	√	√	√

4.4.2 API Process Description

At present, there are two groups of APIs that can be used on RK356X/RK3588, namely the general API interface and the API interface for the zero-copy process, but **RV1106/RV1103 only support the API interface for the zero-copy process**. The main difference between the two sets of APIs is that each time the general interface updates the frame data, the data allocated externally needs to be copied to the input memory of the NPU during runtime, while the interface of the zero-copy process uses pre-allocated memory directly (including memory created by NPU or other frame, such as DRM), reducing the cost of copying memory. When the user input data has only an virtual address, only the common API interface can be used; when the user input data has a physical address

or fd, both sets of interfaces can be used.

For the general API interface, the *rknn_input* structure is initialized at first. The frame data is contained in the structure. The input of models is set by using *rknn_inputs_set* function. After the completion of inference, the inference output can be acquired by the *rknn_outputs_get* function and performed for post-processing. The frame data must be updated before inference. The process of general API call is shown in Figure 4-1, and user behavior is indicated by the process in yellow font.

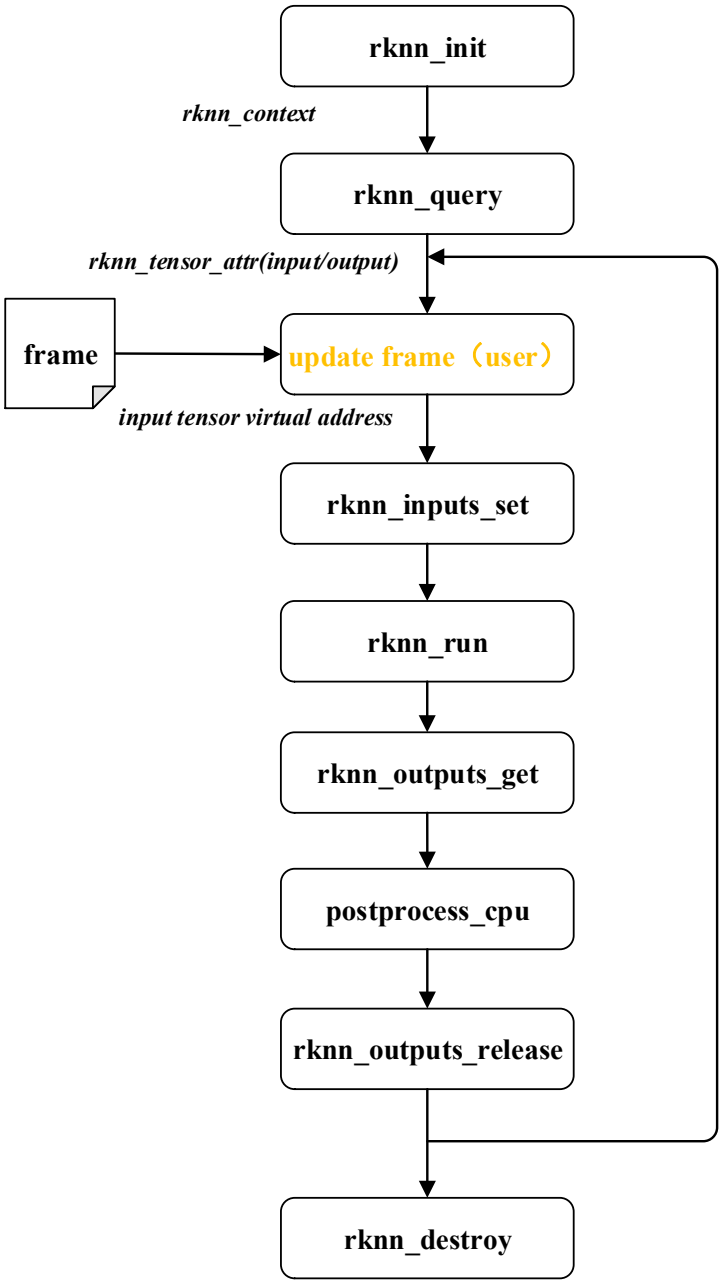

Figure 4-1: General process of calling general interface of API

For the zero-copy interface of API , after allocating memory, the *rknn_tensor_mem* structure is

initialized by the memory information from allocated memory. Creating this structure before the inference is necessary. And the memory information can be retrieved by reading this structure after inference. According to whether the user needs to allocate the modular memory inside model (input/output/weights/intermediate result) and the differences of memory representation (file descriptor/physical address, etc.), there are the following three typical zero-copy calling processes, as shown in Figure 4-2, Figure 4-3 and Figure 4-4 respectively. The red font indicates the interface and data structure specially added for zero copy and the italic indicates the data structure passed between interface calls.

1) Input/Output memory is allocated by API during runtime

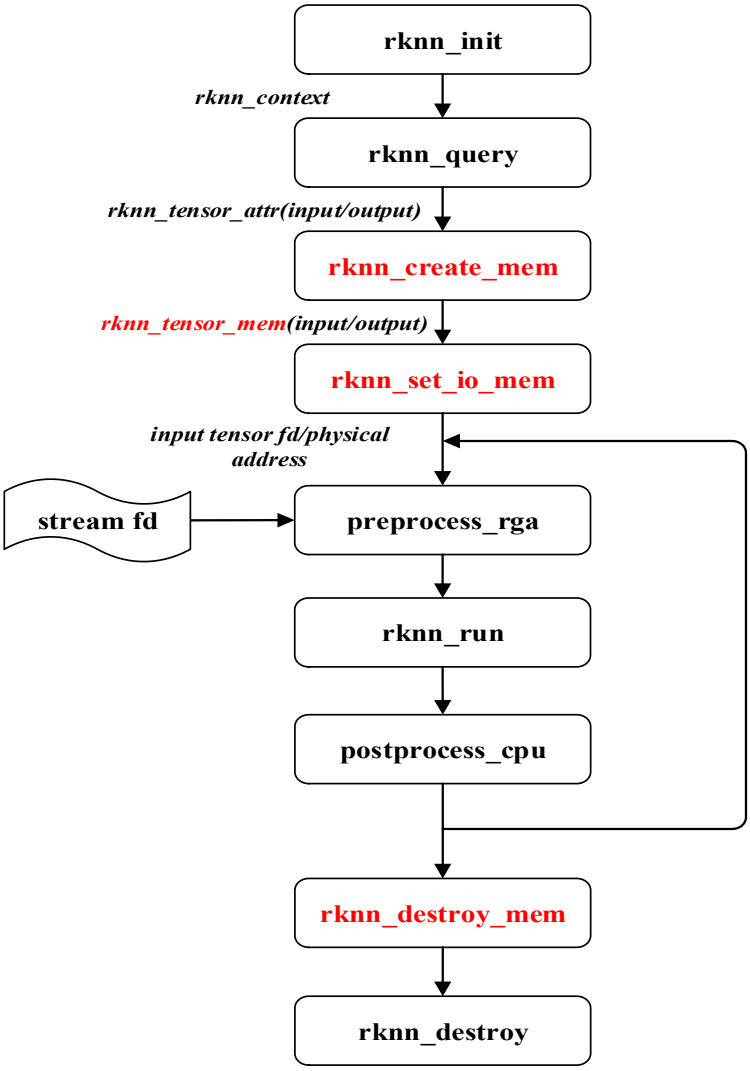

Figure 4-2: Process of zero-copy API interface call (input/output allocated internally)

As shown in Figure 4-2, the input/output memory information structure created by the

rknn_create_mem interface includes the file descriptor and physical addresses. The RGA interface utilizes the memory information allocated by the NPU during runtime. In the above figure, preprocess_rga represents the RGA interface, and stream_fd represents the input source buffer represented by fd in RGA, postprocess_cpu represents the CPU implementation of post processing.

2) Input/output memory is allocated externally

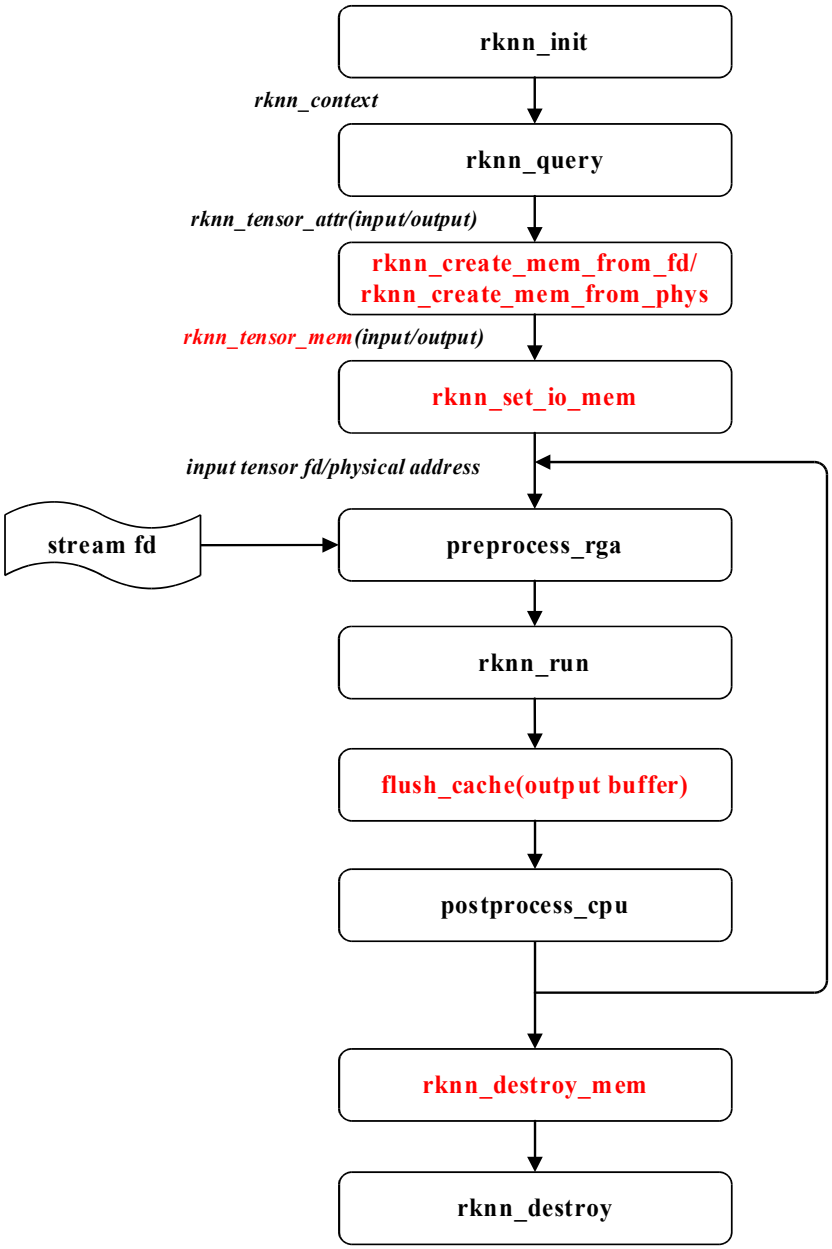

Figure 4-3: The process zero-copy API interface call (input/output allocated externally)

As shown Figure 4-3, flush_cache indicates that the user needs to call the interface associated

with the memory type to flush the output buffer.

3) Input/output/weights/internal tensor memory is allocated externally

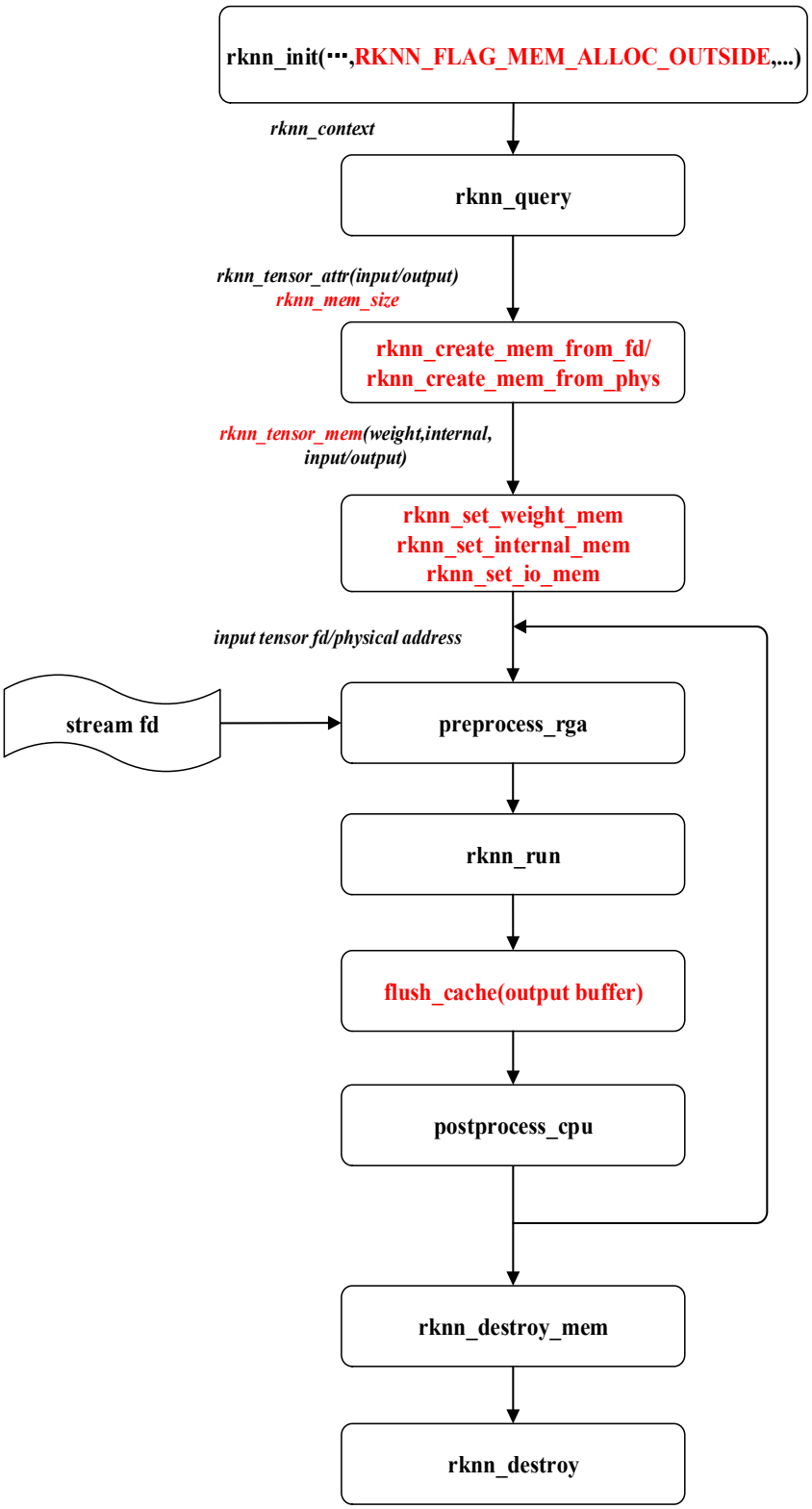

Figure 4-4: The process of zero-copy API interface call (input/output/weights/internal tensor allocated externally)

4.4.2.1 API internal processing flow

When inferring the RKNN model, the original data need to go through three major processes: input processing, running model on NPU, and output processing. Currently, according to different model input formats and quantization methods, there are two different processes inside the general API interface. (**Note: RV1106/RV1103 only supports int8 quantization model, and with uint8 data input with 1 or 3 or 4 channels**)

1) int8 quantized model and the number of input channels is 1 or 3 or 4

The processing flow of the original data is shown in Figure 4-5. Assuming that the input is a 4-channel model, the user must ensure that the color order of the R, G, and B channels is consistent with the training model. Normalization, quantization, and model inference are all running on the NPU. The output data layout format and dequantization process is running on the CPU.

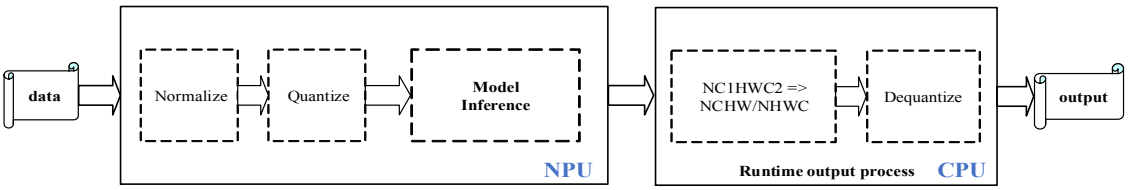

Figure 4-5: Optimized data processing flow

2) int8 quantized model and non-quantized model when number of input channels is 2 or >= 4

The flow of data processing is shown in Figure 4-6. The normalization, quantification, data layout format conversion, and dequantization of data are all running on the CPU except for the inference of the model which runs on the NPU. In this scenario, the processing efficiency of the input data flow would be lower than the optimized one in Figure 4-5.

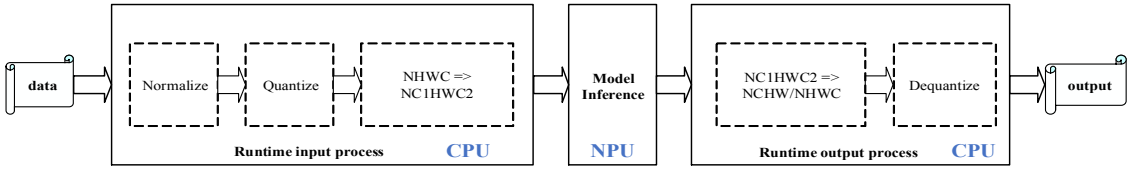

Figure 4-6: Common data processing flow

For the zero-copy API, there is only one processing flow for the internal process of the API, as shown in Figure 4-5. Conditions for using zero copy are listed below:

1. The number of input channels is 1, 3 or 4.

2. The input width is 8 pixel aligned for RK356X, The input width is 16 pixel aligned for RK3588 and RV1106/RV1103 .

3. Int8 asymmetric quantized model.

4.4.2.2 Quantification and Dequantization

The quantization method, quantization data type and quantization parameters used in quantization and dequantization can be queried through the **rknn_query** interface.

At the moment, the NPU of RK3566/RK3568/RV1106/RV1103 only supports asymmetric quantization, and does not support dynamic fixed-point quantization. The combination of data type and quantization method includes:

- int8 (asymmetric quantization)
- int16 (asymmetric quantization, **not yet implemented**)
- float16 (**unavailable RV1106/RV1103**)

Generally speaking, the normalized data is stored in 32-bit floating point data. For conversion of 32-bit floating point data to 16-bit floating point data, it is better for referring to the IEEE-754 standard. The following describes the quantization process, assuming that the normalized 32-bit floating point data is D.

1) float32 to int8(asymmetric quantization)

Assuming that the asymmetric quantization parameter of the input tensor is S_q, ZP, the data quantization process is expressed as the following formula:

$$D_q = \text{round}\left(\text{clamp}\left(D/S_q + \text{ZP}, -128, 127\right)\right)$$

In the above formula, clamp means to limit the value to a certain range. round means rounding processing.

2) float32 to int16(asymmetric quantization)

Assuming that the asymmetric quantization parameter of the input tensor is S_q, ZP, the data

quantization process is expressed as the following formula:

$$D_q = \text{round}\left(\text{clamp}\left(D/S_q + \text{ZP}, -32768, 32767\right)\right)$$

The dequantization process is the inverse process of quantization, and the dequantization formula can be deduced according to the above quantization formula, which will not be repeated here.

4.4.3 API Reference

4.4.3.1 rknn_init

The rknn_init will do the following things, such as, creating the *rknn_context* object, loading the RKNN model, and performing specific initialization behaviors according to the flag and *rknn_init_extend* structure.

API	rknn_init
Description	Initialize rknn
Parameters	*rknn_context *context*: The pointer of *rknn_context* object. After the function is called, the obejct of the context will be returned with the information.
	*void *model*: Binary data for the RKNN model or the path of RKNN model.
	uint32_t size: When model is stored in binary data, it indicates the size of the model. The size is 0 when model is given as the path.
	uint32_t flag: A specific initialization flag. Now, it only has the following flags. RKNN_FLAG_COLLECT_PERF_MASK: For querying the time it took to run each particular layer during runtime. RKNN_FLAG_MEM_ALLOC_OUTSIDE: Used to indicate that model inputs, outputs, weights, and intermediate tensor memory are all allocated by the user. RKNN_FLAG_SHARE_WEIGHT_MEM：Used to share weight from another model
	rknn_init_extend: The extended information during specific initialization. It is disabled at the moment, which indicates this must be passed by the NULL. If using share weight， it should pass the pointer of another rknn_context pointing to another model
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_context ctx;
int ret = rknn_init(&ctx, model_data, model_data_size, 0, NULL);
```

Explanation:

RKNN_FLAG_MEM_ALLOC_OUTSIDE: Two main functions

1) All memory is allocated by users, which is handy for management of overall memory useage of the whole system.

2) For the case of reusing memory, in particular for the RV1103/1106, in which the memory usage is quite limited, the internal tensor memory from two different models can be resued only when these two models are running in series order (parallel running is not allowed in this cased) . This is same for more than two or three models for sharing internal tensor memory

The example code is shown below.

```
rknn_context ctx_a, ctx_b;

rknn_init(&ctx_a, model_path_a, 0, RKNN_FLAG_MEM_ALLOC_OUTSIDE, NULL);
rknn_query(ctx_a, RKNN_QUERY_MEM_SIZE, &mem_size_a, sizeof(mem_size_a));

rknn_init(&ctx_b, model_path_b, 0, RKNN_FLAG_MEM_ALLOC_OUTSIDE, NULL);
rknn_query(ctx_b, RKNN_QUERY_MEM_SIZE, &mem_size_b, sizeof(mem_size_b));

max_internal_size = MAX(mem_size_a.total_internal_size, mem_size_b.total_internal_size);
internal_mem_max = rknn_create_mem(ctx_a, max_internal_size);

internal_mem_a = rknn_create_mem_from_fd(ctx_a, internal_mem_max->fd,
      internal_mem_max->virt_addr, mem_size_a.total_internal_size, 0);
rknn_set_internal_mem(ctx_a, internal_mem_a);

internal_mem_b = rknn_create_mem_from_fd(ctx_b, internal_mem_max->fd,
      internal_mem_max->virt_addr, mem_size_a.total_internal_size, 0);
rknn_set_internal_mem(ctx_b, internal_mem_b);
```

RKNN_FLAG_SHARE_WEIGHT_MEM: It is used for models with various input length, especially for some natural language models. Due to the fact that NPU cannot support flexible input length, it is required to have multiple models difference only in input resolution. Thus, the weight can be shared between models since they all have the same weights.

The following are steps for showing how to use this flag:

Assuming A and B model,

1) Using rknn toolkit2 for generating model A with the input resolution A

2) Using rknn toolkit2 for generating model B without weight with input resolution B, which can be done via remove_weight in rknn.config() in rknn toolkit2. This can reduce the size of model B.

3) Initialize the model A ,

4) Initialize the model B with this flag.

5) Then following the instruction as described:

```
rknn_context ctx_a, ctx_b;
rknn_init(&ctx_a, model_path_a, 0, 0, NULL);

rknn_init_extend extend;
extend.ctx = ctx_a;
rknn_init(&ctx_b, model_path_b, 0, RKNN_FLAG_SHARE_WEIGHT_MEM, &extend);
```

4.4.3.2 rknn_set_core_mask

This function sets the specific cores running inside the NPU. For now, it only works at the RK3588 (including 3 NPU cores). It will return the error code if it is set on RK356X/RV1106/RV1103.

API	rknn_set_core_mask
Description	Set the cores for the NPU.
Parameters	*rknn_context context*: The object of rknn context.
	rknn_core_mask core_mask: The specification of NPU core setting. It has the following choices: **RKNN_NPU_CORE_AUTO** : Referring to automatic mode, meaning that it will select the idle core inside the NPU. **RKNN_NPU_CORE_0** : Running on the NPU0 core **RKNN_NPU_CORE_1**: Runing on the NPU1 core **RKNN_NPU_CORE_2**: Runing on the NPU2 core **RKNN_NPU_CORE_0_1**: Running on both NPU0 and NPU1 core simultaneously. **RKNN_NPU_CORE_0_1_2**: Running on both NPU0, NPU1 and NPU2 simultaneously.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_context ctx;
rknn_core_mask core_mask = RKNN_NPU_CORE_0;
int ret = rknn_set_core_mask(ctx, core_mask);
```

For multi-cores mode (when enabling RKNN_NPU_CORE_0_1 and RKNN_NPU_CORE_0_1_2), the following ops have better acceleration :

Conv, DepthwiseConvolution, Add, Concat, Relu, Clip, Relu6, ThresholdedRelu. Prelu, LeakyRelu.

Other type of op will fallback to Core0 to continue running. In the future update, some ops like Pool or ConvTranpose will be supported.

4.4.3.3 rknn_dup_context

The rknn_dup_context creates a new context object referring to the same model. The new

context is useful in the condition where the weight of the model need to be reused during executing the same model on the multi-thread. (**Unavailable for RV1106/RV1103**)

API	rknn_dup_context
Description	Creates a new context for the same model, to reuse the weight of the model.
Parameters	*rknn_context *context_in*: The pointer of *rknn_context* object. After the function is called, the obejct of the input context will be initialized.
	*rknn_context *context_out*: The pointer of a *rknn_context* output object where information about this new created object is returned.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_context ctx_in;
rknn_context ctx_out;
int ret = rknn_dup_context(&ctx_in, &ctx_out);
```

4.4.3.4 rknn_destroy

This function is used to release the rknn_context and its related resources.

API	rknn_destroy
Description	Destroy the *rknn_context* object and its related resources.
Parameters	*rknn_context context*: The *rknn_context* object that is going to be destroyed.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_context ctx;
int ret = rknn_destroy(ctx);
```

4.4.3.5 rknn_query

The rknn_query function can query the information of models and SDK, including model input and output information, layer-by-layer running time, total model inference time, SDK version, memory usage information, user-defined strings and other information.

API	rknn_query
Description	Query the information about the model and the SDK.
Parameters	*rknn_context context*: The object of rknn_contex.
	rknn_query_cmd : The query command.
	void info*: The structure object that stores the result of the query.
	uint32_t size: The size of the info structure object.
Return	int: Error code (See RKNN Error Code).

Currently, the SDK supports following query commands:

Query command	Return result structure	Function
RKNN_QUERY_IN_OUT_NUM	rknn_input_output_num	Query the number of input and output Tensors.
RKNN_QUERY_INPUT_ATTR	rknn_tensor_attr	Query the input Tensor attribute.
RKNN_QUERY_OUTPUT_ATTR	rknn_tensor_attr	Query the output Tensor attribute.
RKNN_QUERY_PERF_DETAIL	rknn_perf_detail	Query the running time of each layer of the network. It only works when the flag of **RKNN_FLAG_COLLECT_PERF_MASK** is set via using the rknn_init.
RKNN_QUERY_PERF_RUN	rknn_perf_run	Query the total time of inference (excluding time in setting input/output) in microseconds .
RKNN_QUERY_SDK_VERSION	rknn_sdk_version	Query the SDK version.
RKNN_QUERY_MEM_SIZE	rknn_mem_size	Query the memory size allocated for the weights and internal tensors in the network.
RKNN_QUERY_CUSTOM_STRING	rknn_custom_string	Query the user-defined strings in the RKNN model.
RKNN_QUERY_NATIVE_INPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, it queries the native input Tensor attribute, which is the model input attribute directly read by the NPU.
RKNN_QUERY_NATIVE_OUTPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, query the native output Tensor attribute, which is the model output attribute directly from the NPU.
RKNN_QUERY_NATIVE_NC1HWC2_INPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, it queries the native input Tensor attribute, which is the model input attribute directly read by the NPU.it is same with RKNN_QUERY_NATIVE_INPUT_ATTR
RKNN_QUERY_NATIVE_NC1HWC2_OUTPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, it queries the native output

		Tensor attribute, which is the model input attribute directly read by the NPU.it is same with RKNN_QUERY_NATIVE_OUTPUT_ATTR
RKNN_QUERY_NATIVE_NHWC_INPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, it queries the native input Tensor attribute, which is the model input attribute directly read by the NPU.it is same with RKNN_QUERY_NATIVE_INPUT_ATTR
RKNN_QUERY_NATIVE_NHWC_OUTPUT_ATTR	rknn_tensor_attr	When using the zero-copy API interface, it queries the native output NHWC Tensor attribute, which is the model input attribute directly read by the NPU

Next we will explain each query command in detail.

1） Query the SDK version

The RKNN_*QUERY_SDK_VERSION* command can be used to query the version information of the RKNN SDK. You need to create the *rknn_sdk_version* structure object first.

Sample Code:

```
rknn_sdk_version version;
ret = rknn_query(ctx, RKNN_QUERY_SDK_VERSION, &version,
                 sizeof(rknn_sdk_version));
printf("sdk api version: %s\n", version.api_version);
printf("driver version: %s\n", version.drv_version);
```

2） Query the number of input and output Tensor

The *RKNN_QUERY_IN_OUT_NUM* command can be used to query the number of model input and output Tensor. You need to create the *rknn_input_output_num* structure object first.

Sample Code:

```
rknn_input_output_num  io_num;
ret = rknn_query(ctx, RKNN_QUERY_IN_OUT_NUM, &io_num,
                 sizeof(io_num));
printf("model input num: %d, output num: %d\n", io_num.n_input,
                 io_num.n_output);
```

3） Query input Tensor attribute (for general API interface)

The *RKNN_QUERY_INPUT_ATTR* command can be used to query the attribute of the model input Tensor. You need to create the *rknn_tensor_attr* structure object first. (**Note: the tensor queried byRV1106/RV1103 is the tensor originally entered as native**)

Sample Code:

```
rknn_tensor_attr  input_attrs[io_num.n_input];
memset(input_attrs, 0, sizeof(input_attrs));
for (int i = 0; i < io_num.n_input; i++) {
   input_attrs[i].index = i;
   ret = rknn_query(ctx, RKNN_QUERY_INPUT_ATTR, &(input_attrs[i]),
                    sizeof(rknn_tensor_attr));
}
```

4） Query output Tensor attribute (for general API interface)

The *RKNN_QUERY_OUTPUT_ATTR* command can be used to query the attribute of the model output Tensor. You need to create the *rknn_tensor_attr* structure object first.

Sample Code:

```
rknn_tensor_attr output_attrs[io_num.n_output];
memset(output_attrs, 0, sizeof(output_attrs));
for (int i = 0; i < io_num.n_output; i++) {
   output_attrs[i].index = i;
   ret = rknn_query(ctx, RKNN_QUERY_OUTPUT_ATTR, &(output_attrs[i]),
                    sizeof(rknn_tensor_attr));
}
```

5） Query layer-by-layer inference time of model

After the rknn_run interface is called, the *RKNN_QUERY_PERF_DETAIL* command can be used to query the layer-by-layer inference time in microseconds. The premise of using this command is that the flag parameter of the rknn_init interface needs to include the

RKNN_FLAG_COLLECT_PERF_MASK flag.

Sample Code:

```
rknn_context ctx;
int ret = rknn_init(&ctx, model_data, model_data_size,
                    RKNN_FLAG_COLLECT_PERF_MASK, NULL);
...
ret = rknn_run(ctx,NULL);
...
rknn_perf_detail perf_detail;
ret = rknn_query(ctx, RKNN_QUERY_PERF_DETAIL, &perf_detail,
                    sizeof(perf_detail));
```

6） Query total inference time of model

After the rknn_run interface is called, the *RKNN_QUERY_PERF_RUN* command can be used to query the inference time of the model (not including setting input/output) in microseconds.

Sample Code:

```
rknn_context ctx;
int ret = rknn_init(&ctx, model_data, model_data_size, 0, NULL);
...
ret = rknn_run(ctx,NULL);
...
rknn_perf_run perf_run;
ret = rknn_query(ctx, RKNN_QUERY_PERF_RUN, &perf_run,
                    sizeof(perf_run));
```

7） **Query the memory allocation of the model**

After the rknn_init interface is called, when the user needs to allocate memory for network by themself, the *RKNN_QUERY_MEM_SIZE* command can be used to query the weights of the model and the internal memory (excluding input and output) in the network. The requirement of using this command is that the flag parameter of the rknn_init interface needs to enable the RKNN_FLAG_MEM_ALLOC_OUTSIDE flag.

Sample Code:

```
rknn_context ctx;
int ret = rknn_init(&ctx, model_data, model_data_size,
                    RKNN_FLAG_MEM_ALLOC_OUTSIDE , NULL);
rknn_mem_size mem_size;
ret = rknn_query(ctx, RKNN_QUERY_MEM_SIZE, &mem_size,
                    sizeof(mem_size));
```

8） Query User-defined string in the model

After the rknn_init interface is called, if the user has added custom strings when generating the RKNN model, the *RKNN_QUERY_CUSTOM_STRING* command can be used to retrieve user-defined strings.

Sample Code:

```
rknn_context ctx;
int ret = rknn_init(&ctx, model_data, model_data_size, 0, NULL);
rknn_custom_string custom_string;
ret = rknn_query(ctx, RKNN_QUERY_CUSTOM_STRING, &custom_string,
                    sizeof(custom_string));
```

9） **Query native input tensor attribute (for zero-copy API interface)**

The *RKNN_QUERY_NATIVE_INPUT_ATTR* command can be used to query the native attribute of the model input Tensor. User need to create the *rknn_tensor_attr* structure object first.

Sample Code:

```
rknn_tensor_attr input_attrs[io_num.n_input];
memset(input_attrs, 0, sizeof(input_attrs));
for (int i = 0; i < io_num.n_input; i++) {
   input_attrs[i].index = i;
   ret = rknn_query(ctx, RKNN_QUERY_NATIVE_INPUT_ATTR,
                        &(input_attrs[i]), sizeof(rknn_tensor_attr));
}
```

10） Query native output tensor attribute (for zero-copy API interface)

The *RKNN_QUERY_NATIVE_OUTPUT_ATTR* command can be used to query the native attribute of the model output Tensor. User need to create the *rknn_tensor_attr* structure object first.

Sample Code:

```
rknn_tensor_attr output_attrs[io_num.n_output];
memset(output_attrs, 0, sizeof(output_attrs));
for (int i = 0; i < io_num.n_output; i++) {
   output_attrs[i].index = i;
   ret = rknn_query(ctx, RKNN_QUERY_NATIVE_OUTPUT_ATTR,
                                &(output_attrs[i]), sizeof(rknn_tensor_attr));
}
```

11） Query native output tensor attribute (for zero-copy API interface)

The *RKNN_QUERY_NATIVE_NHWC_INPUT_ATTR* command can be used to query the NHWC attribute of the model input Tensor. User need to create the *rknn_tensor_attr* structure object first.

```
rknn_tensor_attr input_attrs[io_num.n_input];
memset(input_attrs, 0, sizeof(input_attrs));
for (int i = 0; i <sdk>/rknpu2/runtime io_num.n_input; i++) {
input_attrs[i].index = i;
ret = rknn_query(ctx, RKNN_QUERY_NATIVE_NHWC_INPUT_ATTR,
                            &(input_attrs[i]), sizeof(rknn_tensor_attr));
}
```

12） Query native output tensor attribute (for zero-copy API interface)

The *RKNN_QUERY_NATIVE_NHWC_OUTPUT_ATTR* command can be used to query the NHWC attribute of the model output Tensor. User need to create the *rknn_tensor_attr* structure object first.

```
rknn_tensor_attr output_attrs[io_num.n_output];
memset(output_attrs, 0, sizeof(output_attrs));
for (int i = 0; i <sdk>/rknpu2/runtime io_num.n_output; i++) {
output_attrs[i].index = i;
ret = rknn_query(ctx, RKNN_QUERY_NATIVE_NHWC_OUTPUT_ATTR,
                            &(output_attrs[i]), sizeof(rknn_tensor_attr));
}
```

4.4.3.6 rknn_inputs_set

The input data of the model can be set by the rknn_inputs_set function. This function can support multiple inputs, each of which is a *rknn_input* structure object. The user needs to set these object field before passing in *rknn_inputs_set* function. (**Note: unavailable on RV1106/RV1103**)

API	rknn_inputs_set

Description	Set the model input data.
Parameter	*rknn_context context*: The object of rknn_contex.
	uint32_t n_inputs: Number of inputs.
	rknn_input inputs[]: Array of rknn_input.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_input inputs[1];
memset(inputs, 0, sizeof(inputs));
inputs[0].index = 0;
inputs[0].type = RKNN_TENSOR_UINT8;
inputs[0].size = img_width*img_height*img_channels;
inputs[0].fmt = RKNN_TENSOR_NHWC;
inputs[0].buf = in_data;
inputs[0].pass_through = 0;

ret = rknn_inputs_set(ctx, 1, inputs);
```

4.4.3.7 rknn_run

The rknn_run function will perform a model inference. The input data need to be configured by the *rknn_inputs_set* function or zero-copy interface before *rknn_run is* called.

API	rknn_run
Description	Perform a model inference.
Parameter	*rknn_context context*: The object of rknn_contex.
	rknn_run_extend extend*: Reserved for extension. It is not used currently and accepted NULL only.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
ret = rknn_run(ctx, NULL);
```

4.4.3.8 rknn_wait

This interface is used for non-blocking mode inference and **has not been implemented yet**.

4.4.3.9 rknn_outputs_get

The rknn_outputs_get function can get the output data from the model. This function can get multiple output data, each of which is a *rknn_output* structure object that needs to be created and initialized in turn before the function is called. (**Note: RV1106/RV1103 unsupported**)

There are two ways to store buffers for output data:

1) The user allocate and release buffers themselves. In this case, the *rknn_output.is_prealloc* needs to be set to 1, and the *rknn_output.buf* points to users' allocated buffer;
2) The other is allocated by rknn. At this time, the *rknn_output .is_prealloc* needs to be set to 0. After the function is executed, *rknn_output.buf* will be created and store the output data.

API	rknn_outputs_get
Description	Get model inference output data.
Parameter	*rknn_context context*: The object of rknn_context.
	uint32_t n_outputs: Number of output.
	rknn_output outputs[]: Array of rknn_output.
	rknn_run_extend extend*: Reserved for extension, currently not used yet. Accepting NULL only.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_output outputs[io_num.n_output];
memset(outputs, 0, sizeof(outputs));
for (int i = 0; i < io_num.n_output; i++) {
   outputs[i].index = i;
   outputs[i].is_prealloc = 0;
   outputs[i].want_float = 1;
}
ret = rknn_outputs_get(ctx, io_num.n_output, outputs, NULL);
```

4.4.3.10 rknn_outputs_release

The rknn_outputs_release function will release the relevant resources of the *rknn_output* object.

API	rknn_outputs_release
Description	Release the rknn_output object
Parameter	*rknn_context context*: rknn_context object
	uint32_t n_outputs: Number of output.
	rknn_output outputs[]: The array of rknn_output to be released.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
ret = rknn_outputs_release(ctx, io_num.n_output, outputs);
```

4.4.3.11 rknn_create_mem_from_mb_blk

It has not been implemented Currently.

4.4.3.12 rknn_create_mem_from_phys

When the user wants to allocate memory for NPU, the rknn_create_mem_from_phys function can create a *rknn_tensor_mem* structure and return its pointer. This function will pass the physical address, virtual address and size, and the information related to the external memory to the *rknn_tensor_mem* structure.

API	rknn_create_mem_from_phys
Description	Create rknn_tensor_mem structure and allocate memory through physical address
Parameter	*rknn_context context*: rknn_context object.
	uint64_t phys_addr: The physical address of buffer.
	*void *virt_addr:* The virtual address of buffer.
	uint32_t size: The size of buffer.
Return	*rknn_tensor_mem*:* The tensor memory information structure pointer.

Sample Code:

```
//suppose we have got buffer information as input_phys, input_virt and size
rknn_tensor_mem* input_mems [1];
input_mems[0] = rknn_create_mem_from_phys(ctx, input_phys, input_virt, size);
```

4.4.3.13 rknn_create_mem_from_fd

When the user wants to allocate the memory for NPU, the rknn_create_mem_from_fd creates a *rknn_tensor_mem* structure and return its pointer. This function filled with the file descriptor, logical address and size, and the information related to the external memory will be assigned to the *rknn_tensor_mem* structure.

API	rknn_create_mem_from_fd
Description	Create rknn_tensor_mem structure and allocate memory through file descriptor
Parameter	*rknn_context context*: rknn_context object.
	int32_t fd: The file descriptor of buffer.
	*void *virt_addr*: The virtual address of buffer, which indicates the beginning of fd.
	uint32_t size: The size of buffer.
	int32_t offset: The offset corresponding for file descriptor and virtual address
Return	rknn_tensor_mem*: The tensor memory information structure pointer.

Sample Code:

```
//suppose we have got buffer information as input_fd, input_virt and size
rknn_tensor_mem* input_mems [1];
input_mems[0] = rknn_create_mem_from_fd(ctx, input_fd, input_virt, size, 0);
```

4.4.3.14 rknn_create_mem

When the user wants to allocate memory which can be used directly in the NPU, the rknn_create_mem function can create a *rknn_tensor_mem* structure and get its pointer. This function passes in the memory size and initializes the *rknn_tensor_mem* structure at runtime.

API	rknn_create_mem
Description	Create rknn_tensor_mem structure internally and allocate memory during runtime
Parameter	*rknn_context context*: rknn_context object.
	uint32_t size: The size of buffer.
Return	*rknn_tensor_mem**: The tensor memory information structure pointer.

Sample Code:

```
//suppose we have got buffer size
rknn_tensor_mem* input_mems [1];
input_mems[0] = rknn_create_mem(ctx, size);
```

4.4.3.15 rknn_destroy_mem

The rknn_destroy_mem function destroys the rknn_tensor_mem structure. However, the memory allocated by the user needs to be released manually.

API	rknn_destroy_mem
Description	Destroy rknn_tensor_mem structure
Parameter	*rknn_context context*: rknn_context object.
	rknn_tensor_mem:* The tensor memory information structure pointer.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_tensor_mem* input_mems [1];
int ret = rknn_destroy_mem(ctx, input_mems[0]);
```

4.4.3.16 rknn_set_weight_mem

If the user has allocated memory for the network weights, after initializing the corresponding *rknn_tensor_mem* structure, the NPU can use the memory through the rknn_set_weight_mem function. This function must be called before calling rknn_run.

API	rknn_set_weight_mem
Description	Set up the rknn_tensor_mem structure containing weights memory information
Parameter	*rknn_context context*: rknn_context object.
	rknn_tensor_mem:* The tensor memory information structure pointer.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_tensor_mem* weight_mems [1];
int ret = rknn_set_weight_mem(ctx, weight_mems[0]);
```

4.4.3.17 rknn_set_internal_mem

If the user has allocated memory for the internal tensor in network, after initializing the corresponding rknn_tensor_mem structure, the NPU can use the memory through the rknn_set_internal_mem function. This function must be called before calling rknn_run.

API	rknn_set_internal_mem
Description	Set up the rknn_tensor_mem structure containing internal tensor memory information in network
Parameter	*rknn_context context*: rknn_context object.
	rknn_tensor_mem:* The pointer to the tensor memory information structure.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_tensor_mem* internal_tensor_mems [1];
int ret = rknn_set_internal_mem(ctx, internal_tensor_mems[0]);
```

4.4.3.18 rknn_set_io_mem

If the user has allocated memory for the input/output tensor in network, after initializing the corresponding *rknn_tensor_mem* structure, the NPU can use the memory through the rknn_set_io_mem function. This function must be called before calling rknn_run.

API	rknn_set_io_mem
Description	Set up the rknn_tensor_mem structure containing input/output tensor memory information in network
Parameter	*rknn_context context*: rknn_context object.
	rknn_tensor_mem:* The pointer to the tensor memory information structure .
	rknn_tensor_attr *: The attribute of input or output tensor buffer.
Return	int: Error code (See RKNN Error Code).

Sample Code:

```
rknn_tensor_attr output_attrs[1];
rknn_tensor_mem* output_mems[1];

ret = rknn_query(ctx, RKNN_QUERY_NATIVE_OUTPUT_ATTR, &(output_attrs[0]),
sizeof(rknn_tensor_attr));
output_mems[0] = rknn_create_mem(ctx, output_attrs[0].size_with_stride);
rknn_set_io_mem(ctx, output_mems[0], &output_attrs[0]);
```

4.4.4 RKNN Definition of Data Structcture

4.4.4.1 rknn_sdk_version

The structure *rknn_sdk_version* is used to indicate the version information of the RKNN SDK. The following table shows the definition:

Field	Type	Meaning
api_version	char[]	SDK API version information.
drv_version	char[]	SDK driver version information.

4.4.4.2 rknn_input_output_num

The structure *rknn_input_output_num* represents the number of input and output Tensor， The following table shows the definition:

Field	Type	Meaning
n_input	uint32_t	The number of input tensor
n_output	uint32_t	The number of output tensor

4.4.4.3 rknn_tensor_attr

The structure *rknn_tensor_attr* represents the attribute of the model's Tensor. The following table shows the definition:

Field	Type	Meaning
index	uint32_t	Indicates the index position of the input and output Tensor.
n_dims	uint32_t	The number of Tensor dimensions.
dims	uint32_t[]	Values for each dimension.
name	char[]	Tensor name.
n_elems	uint32_t	The number of Tensor data elements.
size	uint32_t	The memory size of Tensor data.
fmt	rknn_tensor_format	The format of Tensor dimension, has the following format: **RKNN_TENSOR_NCHW** **RKNN_TENSOR_NHWC** **RKNN_TENSOR_NC1HWC2**
type	rknn_tensor_type	Tensor data type, has the following data types: **RKNN_TENSOR_FLOAT32** **RKNN_TENSOR_FLOAT16** **RKNN_TENSOR_INT8** **RKNN_TENSOR_UINT8** **RKNN_TENSOR_INT16** **RKNN_TENSOR_UINT16** **RKNN_TENSOR_INT32** **RKNN_TENSOR_INT64** **RKNN_TENSOR_BOOL**
qnt_type	rknn_tensor_qnt_type	Tensor Quantization Type, has the following types of quantization: **RKNN_TENSOR_QNT_NONE:** Not quantized; **RKNN_TENSOR_QNT_DFP**: Dynamic fixed point quantization; **RKNN_TENSOR_QNT_AFFINE_ASYMMETRIC**: Asymmetric quantification.
fl	int8_t	RKNN_TENSOR_QNT_DFP: quantization parameter
scale	float	RKNN_TENSOR_QNT_AFFINE_ASYMMETRIC: quantization parameter.

w_stride	uint32_t	The number of pixels that actually store one line of image data, which is equal to the number of valid data pixels in one row + the number of invalid pixels that are filled in for the hardware to quickly jump to the next line. (unit: per pixel)
size_with_stride	uint32_t	The actual byte size of image data (including the byte size of filled invalid pixels).
pass_through	uint8_t	0: means unconverted data. 1: means converted data, Note: Conversion includes normalization and quantization.
h_stride	uint32_t	This is only used in the context of multi-batch input and can be set by users. The purpose of this is to allow NPU to read out beginning of memory address for every batch correctly. It is equivalent of original model input height + the number of invalid pixels that are filled in for the hardware to quickly jump to the next line . If its value is 0, it is the same as model input height. (unit: per pixel)

4.4.4.4 rknn_perf_detail

The structure rknn_perf_detail represents the performance details of the model. The definition of the structure is shown in the following table: (**Note: RV1106/RV1103 unsupported**)

Field	Type	Meaning
perf_data	char*	The performance details contain the running time of each layer of the network stored in string type.
data_len	uint64_t	The data length of string type of perf_data

4.4.4.5 rknn_perf_run

The structure rknn_perf_run represents the total inference time of the model. The definition of the structure is shown in the following table: (**Note: RV1106/RV1103 unsupported**)

Field	Type	Meaning
run_duration	int64_t	The total inference time of the network (not including setting input/output) in microseconds.

4.4.4.6 rknn_mem_size

The structure *rknn_mem_size* represents the memory allocation when the model is initialized. The definition of the structure is shown in the following table:

Field	Type	Meaning
total_weight_size	uint32_t	The memory size allocated for weights of the network.
total_internal_size	uint32_t	The memory size allocated for internal tensor of the network.
total_dma_allocated_size	uint64_t	All dma memory size allocated for the network.
total_sram_size	uint32_t	Only for RK3588, memory size of SRAM reserved for NPU. (Referring to the <<RK3588_NPU_SRAM_usage.md>> for more details)
free_sram_size	uint32_t	Only for RK3588, the current available SRAM (Referring to the <<RK3588_NPU_SRAM_usage.md>> for more details)
reserved[12]	uint32_t	reserve

4.4.4.7 rknn_tensor_mem

The structure *rknn_tensor_mem* represents the tensor memory information. The definition of the structure is shown in the following table:

Field	Type	Meaning
virt_addr	void*	The virtual address of tensor.
phys_addr	uint64_t	The physical address of tensor.
fd	int32_t	The file descriptor of tensor.
offset	int32_t	The offset of fd and virtual address.
size	uint32_t	The actual size of tensor.
flags	uint32_t	rknn_tensor_mem has the following type of flags: **RKNN_TENSOR_MEMORY_FALGS_ALLOC_INSIDE:** indicates that the rknn_tensor_mem structure is created during runtime. **RKNN_TENSOR_MEMORY_FLAGS_FROM_FD:** It represents the rknn_tensor_mem created by fd. **RKNN_TENSOR_MEMORY_FLAGS_FROM_PHYS:** It represents rknn_tensor_mem created by physical address. The user does not need to pay attention to the flags.
priv_data	void*	private data.

4.4.4.8 rknn_input

The structure *rknn_input* represents a data input to the model, used as a parameter to the rknn_inputs_set function. The following table shows the definition:

Field	Type	Meaning
index	uint32_t	The index position of this input.
buf	void*	The pointer of the input data buffer.
size	uint32_t	The memory size of the input data buffer.
pass_through	uint8_t	When set to 1, buf will be directly set to the input node of the model without any pre-processing.
type	rknn_tensor_type	The type of input data.
fmt	rknn_tensor_format	The format of input data.

4.4.4.9 rknn_output

The structure *rknn_output* represents a data output of the model, used as a parameter to the rknn_outputs_get function. This structure will be assigned with data after calling rknn_outputs_get. The following table shows the definition of each member of *rknn_output*:

Field	Type	Meaning
want_float	uint8_t	Indicates whether the output data needs to be converted to float type.
is_prealloc	uint8_t	Indicates whether the buffer that stores the output data is pre-allocated.
index	uint32_t	The index position of this output.
buf	void*	The pointer pointing to the output data buffer.
size	uint32_t	Output data buffer size in byte.

4.4.4.10 rknn_init_extend

The structure *rknn_init_extend* represents the extended information when the model is initialized. **It is not available currently on RV1106/RV1103**. The definition of the structure is shown in the following table:

Field	Type	Meaning
ctx	rknn_context	The initialized rknn_context object.
real_model_offset	int32_t	The real offset that is in .rknn model file. Only valid when using file path as initialized parameter
real_model_size	uint32_t	The real size of rknn model file. Only valid when using file path as initialized parameter
reserved	uint8_t[120]	The reserved data.

4.4.4.11 rknn_run_extend

The structure *rknn_run_extend* represents the extended information during model inference. **It is not available currently**. The definition of the structure is shown in the following table:

Field	Type	Meaning

frame_id	uint64_t	The index of frame of current inference.
non_block	int32_t	0 means blocking mode, 1 means non-blocking mode, non-blocking mode means that the rknn_run call returns immediately.
timeout_ms	int32_t	The timeout of inference in milliseconds.
fence_fd	int32_t	For the non-blocking inference. (**Not Available**)

4.4.4.12 rknn_output_extend

The structure *rknn_output_extend* means to obtain the extended information of the output. **It is not available currently**. The definition of the structure is shown in the following table:

Field	Type	Meaning
frame_id	int32_t	The frame index of the output result.

4.4.4.13 rknn_custom_string

The structure rknn_custom_string represents the custom string set by the user when converting the RKNN model. The definition of the structure is shown in the following table:

Field	Type	Meaning
string	char[]	User-defined string.

4.4.5 Instruction of API Input and Output

4.4.5.1 General Input and Output of API (Non Zero Copy)

Note: RV1106/RV1103 unsupported

1) rknn_inputs_set

When calling this API, it can set up the parameter from rknn_inputs_set, that is, the input data type and size can be configured by the rknn_input input[] .

The detail explanation of input: The pass_through is one of the member of rknn_input structure. If pass_through is set as 1, then the input data will be imported and computed inside the model in which none of the conversion will happen. If it is 0, the input tensor will be conveted first by the rknn api based

on the fmt and type from the rknn_input struct, which is happened inside the RKNN API and fed into model.

When using this rknn_input_set, user should query **RKNN_QUERY_NATIVE_INPUT_ATTR** rather than **RKNN_QUERY_INPUT_ATTR. Depending on the fmt or laypout, the preprocessing is different correspondingly.**

a) When layout is RKNN_TENSOR_NCHW: the input usually is 4 dimensional and data type is bool or int64, when passing to NPU, the data layout need to be arranged as NCHW for NPU.

b) When layout is RKNN_TENSOR_NHWC: the input usually is 4 dimensional and data type is one of the float32/float16/int8/uint8. Also, the number of input channel is either 1, 3 or 4. When passing to NPU, data layout need to be arranged into NHWC layout. It is worth nothing that when setting pass_through is 1, the width may have an alignment with stride depending on the w_stride from rknn_input_attr.

c) When layout is RKNN_TENSOR_NC1HWC2: the input usually is 4 dimensional and data type is float16/int8. Also, the input channel is not 1, 3 and 4. When pass_through is 0, the input data layout need to be arranged as NHWC. When pass_through is 1, the input data layout need to reshaped as RKNN_TENSOR_NC1HWC2.

d) When layout is RKNN_TENSOR_UNDEFINED: Usually, the input is not 4 dimensional. When passing to NPU, the input layout need to arranged according to the input model layout in ONNX!. In this situation, the NPU will not do anything related to process of mean/std and layout conversion.

The relationship between input data type and data type queried from **RKNN_QUERY_INPUT_ATTR** is shown in table below.

Input data type from RKNN_QUERY_INPUT_ATTR	Available Input data type
bool	bool
int8	int8 / uint8 / float32
float16	uint8 / float16 / float32
int64	int64

Table4-1: The available input data type and model input data type

2) rknn_outputs_get

When calling this function, it can set up want_float, which is one of the member of rknn_output structure, to select the input data type, layout, etc. When the rknn-toolkit 2 tool before version 1.2.0 converts the RKNN model, the data type of the output layer is fixed to float32 by default, so even if it is want_ Float = 0, the result of non quantitative model is still float32. In 1.2.0, including the RKNN model converted by the toolkit after 1.2.0, the output of int8 model is int8 data type; In particular, if the last layer of int8 model is float16 output, the model output is float16 data type, for example, the last layer is softmax layer; The float16 model is output as float16 data type.

Table4-2: RK356X/RK3588 supports input configuration without zero copy

want_float	Output data Type	Supported output layout	Remark
1	float32	NCHW	
0	int8	NCHW	Only support i8 model
	float16	NCHW	

4.4.5.2 Input and Output with Zero Copy of API

Two functions need to use for this purpose:

rknn_create_mem,

rknn_set_io_mem

The specification of input data (involving the size, data type, layout, etc.) should be configured according to the actual data that need to be allocated by the zero copy memory.

For RK356X and RK3588, NPU supports the same input configuration the mentioned in the section of **General Input and Output of API**

For RV1106 and RV1103, NPU supports the input configuration as follow:

Table4-3: RV1106/RV1103 supports input configuration with zero copy

Data Type of Input	pass_through	Number of Channels	Supported input layout	Remark
uint8_t	0	-	NHWC	Only support i8 model
int8	1	1,3,4	NHWC	
int8	1	Not 1,3,4 channel	NC1HWC2	**Unsupported currently**

For the output data, when not in the mode of NATIVE_LAYOUT, it is suggested considering the actual data inside the zero copy memory to configure the corresponding size, data type and data layout for output. When in the NATIVE_LAYOUT mode, it is recommended utilizing the default configuration that is from the one queried from the RKNN_QUERY_NATIVE_INPUT_ATTR and data size should adopt to size_with_stride. The specification of output is shown below.

Output Data Type	Available Output Layout	Remark
float32	NCHW	
int8	NCHW	Only support i8 model
int8	NC1HWC2	Only support i8 model
float16	NCHW	
float16	NC1HWC2	Only support fp16 model

Table4-4: RK356X/RK3588 supports output setting. (With zero copy interface)

Output Data Type	Available Output Layout	Remark
float32	NHWC	**Unsupported currently**
int8	NHWC	**Unsupported currently**
int8	NC1HWC2	Only support i8 model

Table4-5: RV1106/RV1103 supports output setting. (With zero copy interface)

4.4.5.3 Instruction of looking up NATIVE_LAYOUT parameter

There are two parameters listed below.

RKNN_QUERY_NATIVE_INPUT_ATTR

RKNN_QUERY_NATIVE_OUTPUT_ATTR

Those two can query the attribute of input and output tensor. In most of the time, this native attribute has the best performance. When querying this attribute, the rknn_tensor_format might be the NC1HWC2, which is a special memory arrangement. The memory address from low to high is C2->W->H->C1->N, among which the C2 has the fastest changing rate and N is the slowest one. The value of C2 may vary depending on the platform and data type. The specification of C2 is shown in the table below.

Table4-6: The value of C2 under different platform

platform	int8(quantization)	float16(non-quantization)	Int16(quantization)
RK356X	8	4	4
RK3588	16	8	8
RV1106/RV1103	16	8	8

For example, assuming on the RK356X, there is an output tensor whose memory layout is 1x1x1x32 (NHWC) from the orignal model. Then, the original model is converted to RKNN model. When querying the output tensor from this new model with the native attribute, the memory layout of this

output tensor will be converted to 1x4x1x1x8 (NC1HWC2), where C1 = [32/8] =4, C2 = 8, the [] denotes the rounding up to cloest integer. Take the NC1HWC2 arrangement of int8 data of RK356X in memory as an example, where C2 = 8, as shown in Figure 4-7.

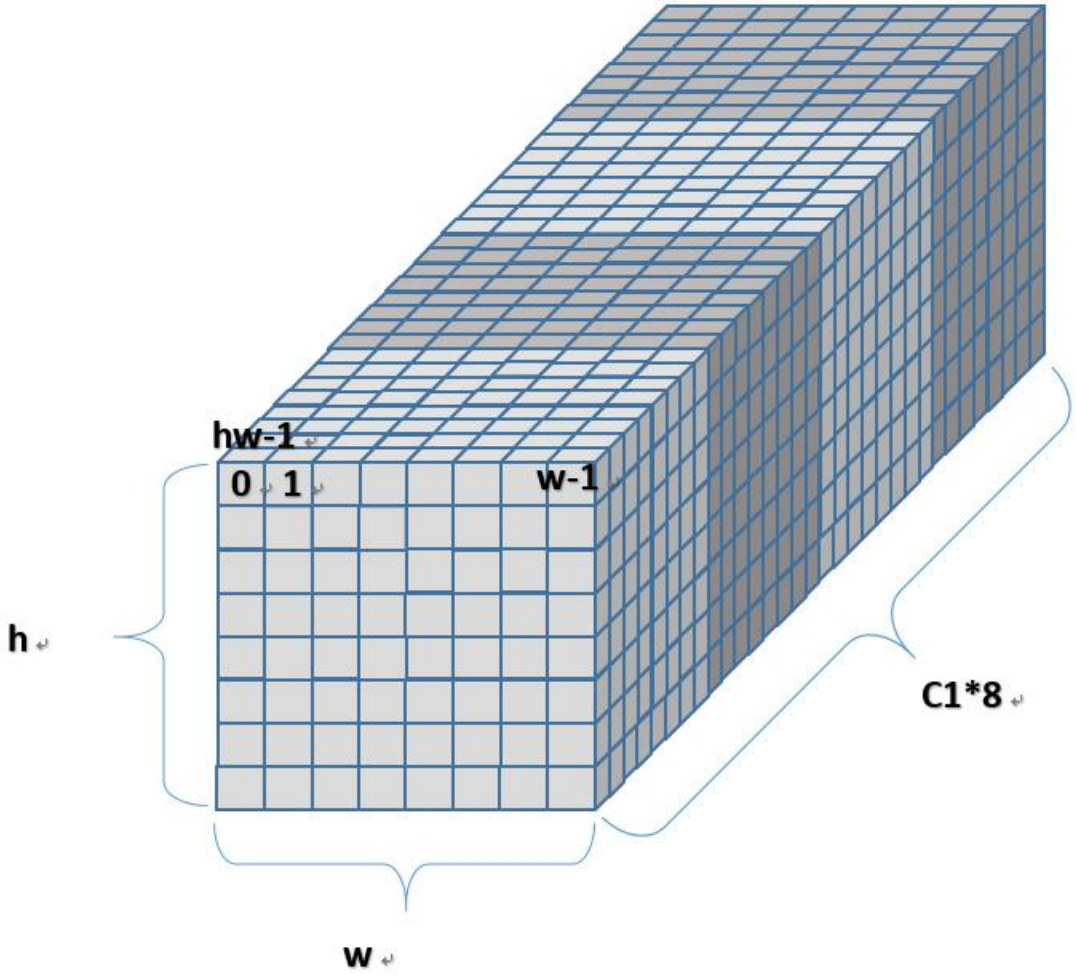

Fig4-7 The arrangement of int8 data of RK356X in NC1HWC2 in memory

（1）NC1HWC2 to NCHW: NC1HWC2 arranged in int8 data is converted to NCHW arranged in int8 data, as shown below.

```
/*
  *src:    NC1HWC2 input tensor addr
  *dst:     NCHW output tensor addr
  *dims:   input  NC1HWC2 shape
  *channel: output NCHW channel value
  * h:       output NCHW h value
  * w:       output NCHW w value
  */
int NC1HWC2_to_NCHW(const int8_t* src, float* dst, int* dims, int channel, int h, int w)
{
  int batch  = dims[0];
  int C1     = dims[1];
  int C2     = dims[4];
  int hw_src = dims[2] * dims[3];
  int hw_dst = h * w;
  for (int i = 0; i < batch; i++) {
   src = src + i * C1 * hw_src * C2;
   dst = dst + i * channel * hw_dst;
   for (int c = 0; c < channel; ++c) {
     int          plane  = c / C2;
     const int8_t* src_c  = plane * hw_src * C2 + src;
     int          offset = c % C2;
     for (int cur_h = 0; cur_h < h; ++cur_h)
       for (int cur_w = 0; cur_w < w; ++cur_w) {
         int cur_hw                    = cur_h * w + cur_w;
         dst[c * hw_dst + cur_h * w + cur_w] = src_c[C2 * cur_hw + offset];
       }
   }
  }

  return 0;
}
```

（2）NC1HWC2 to NHWC: NC1HWC2 arranged in int8 data is converted to NHWC arranged in int8 data, as shown below.

```
/*
  *src:    NC1HWC2 input tensor addr
  *dst:     NCHW output tensor addr
  *dims:   input  NC1HWC2 shape
  *channel: output NCHW channel value
  * h:       output NCHW h value
  * w:       output NCHW w value
  */
int NC1HWC2_to_NHWC(const int8_t* src, float* dst, int* dims, int channel, int hw_dst )
{
    int batch  = dims[0];
    int C1     = dims[1];
    int C2     = dims[4];
    int hw_src = dims[2] * dims[3];
    int hw_dst = h * w;
  for (int i = 0; i < batch; i++) {
    src = src + i * C1 * hw_src * C2;
    dst = dst + i * channel * hw_dst;
    for (int c = 0; c < channel; ++c) {
      int          plane  = c / C2;
      const int8_t* src_c  = plane * hw_src * C2 + src;
      int          offset = c % C2;
      for (int cur_h = 0; cur_h < h; ++cur_h)
        for (int cur_w = 0; cur_w < w; ++cur_w) {
          int cur_hw                    = cur_h * w + cur_w;
          dst[c * hw_dst + cur_h * w + cur_w] = src_c[C2 * cur_hw + offset];
        }
    }
  }
  return 0;
}
```

After calling the rknn_query with **RKNN_QUERY_NATIVE_INPUT_ATTR** or **RKNN_QUERY_NATIVE_OUTPUT_ATTR**, this API will return the configuration with the best performance to the **rknn_tensor_attr**. If the user has got different input or output data configuration differed from what they desire, they can customize the configuration of the query part. However, it must be consistent with the table-**3** and table-**4** shown above. For example, if the queried data type is **uint8** and users want to configure this output data type as **float32**, users should multiply the size in **rknn_tensor_attr** structure by 4 since the float32 is 4 bytes long. Also, the data type in rknn_tensor_attr should be changed to **RKNN_TENSOR_FLOAT32**. With regrading to querying in the native mode using the above two parameters, users should use the zero copy interface to fetch the result of input and

output.

4.4.6 RKNN Error Code

The return code of the RKNN API function is defined as shown in the following table.

Error Code	Message
RKNN_SUCC（0）	Execution is successful
RKNN_ERR_FAIL (-1)	Execution error
RKNN_ERR_TIMEOUT (-2)	Execution timeout
RKNN_ERR_DEVICE_UNAVAILABLE (-3)	NPU device is unavailable
RKNN_ERR_MALLOC_FAIL (-4)	Memory allocation is failed
RKNN_ERR_PARAM_INVALID (-5)	Parameter error
RKNN_ERR_MODEL_INVALID (-6)	RKNN model is invalid
RKNN_ERR_CTX_INVALID (-7)	rknn_context is invalid
RKNN_ERR_INPUT_INVALID (-8)	rknn_input object is invalid
RKNN_ERR_OUTPUT_INVALID (-9)	rknn_output object is invalid
RKNN_ERR_DEVICE_UNMATCH (-10)	Version does not match
RKNN_ERR_INCOMPATILE_OPTIMIZATION_LEVEL_VERSION (-12)	This RKNN model use optimization level mode, but not compatible with current driver.
RKNN_ERR_TARGET_PLATFORM_UNMATCH (-13)	This RKNN model doesn’t compatible with current platform.

4.5 NPU SDK Instruction

4.5.1 SDK Content Explain

The NPU SDK for both RK356X and RK3588 contains examples for the API usage, including the NPU library, server programs, doc. The server program is called rknn_server, which resides on the development board. With the communication set up by the server program, The developer should connect the development board with the PC via the USB and use the rknn-toolkit2 API with python interface to run the model. The detail instruction of how to install is written in <<rknn_server_proxy.md>>.

The overall structure of the content is shown below,

```
├── doc
├── examples                          # Example Program
│   ├── 3rdparty
│   ├── rknn_api_demo                 # Zero Copy API Demo
│   ├── rknn_mobilenet_demo
│   ├── rknn_multiple_input_demo
│   ├── rknn_ssd_demo
│   └── rknn_yolov5_demo
├── README.md
├── rknn_server_proxy.md              # The instruction of server program (used for
│                                     inference with board)
└── runtime
    ├── RK356X                        # RK356X library and content of server program
    │   │                             on the board side
    │   ├── Android
    │   │   ├── librknn_api
    │   │   └── rknn_server
    │   └── Linux
    │       ├── librknn_api
    │       └── rknn_server
    └── RK3588                        # RK3588  library and content of server program
        │                             on the board side
        ├── Android
        │   ├── librknn_api
        │   └── rknn_server
        └── Linux
            ├── librknn_api
            └── rknn_server
    └── RV1106                    # RV1106/RV1103library
            └── Linux
                └── librknn_api
```

4.6 Debugging

4.6.1 Log Level

The library for NPU will rely on the environment variable on the board to generate a set of debugging logs or files that are suitable for developers to debug the program. The command for setting up debugging log is shown below,

```
export  RKNN_LOG_LEVEL=<level_number>
```

, where <level_number> represents the category of debugging log, ranging from 0 to 5. The detail of each type of log is listed below.

Table-4-7: The output log of each category

Level	Output Log
0	Printing error message only
1	Printing both error and warning log
2	Printing both hints and log in level 1
3	Printing both debugging log and log in level 2
4	Printing both log in level 3 and information in each layer, influencing the performance of rknn_run when enabling this log
5	Printing both message in level 4 and output data in intermediate layer, influencing the performance of rknn_run when enabling this log

As an example, for querying the performance of each layer, the developer can set the following environment variable.

```
export RKNN_LOG_LEVEL=4
```

When completing the debugging, to reset the debugging log to level 0, using the following commands,

```
unset RKNN_LOG_LEVEL
```

4.6.2 Printing for each layer

The following setting will open the performance analysis for each layer:

RKNN_DUMP_QUANT:

When the value of this is 0: this will dump float32 in npy format by default. If this value was 1, the output type will be the same type with the model. For instance, the int8 model would have the int8 output type for tensors dump from each layer when this value was 1.

RKNN_DUIMP_DIR:

This will set up the path for saving these output tensors dump from each layer.

RKNN_LOG_LEVEL:

When this value is set as 5, the output tensor will be dumped from each layer saved in npy format.

When this value is set as 6, the output tensor will be saved as format in both npy and txt in NC1HWC2 layout. For example, for saving results dump from each layer by setting these environment variables as shown below.

```
export RKNN_DUMP_QUANT=0
export RKNN_DUMP_DIR =/data/dumps
export RKNN_LOG_LEVEL =5
```

4.6.3 Profiling

4.6.3.1 Checking the environment on the development board

Generally, the frequency of each hardware unit on the development board is not fixed, resulting in the fluctuation and uncertainty on the performance of module running on the board. To avoid this, the developer should fix the frequency of each hardware unit before testing modules for assessment.

1. Fix Frequency for CPU

(1) Query the frequency of CPU

```
cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_cur_freq
or
cat /sys/kernel/debug/clk/clk_summary | grep arm
```

(2) Fix the frequency of CPU

```
# Query avilable frequency of CPU
cat /sys/devices/system/cpu/cpufreq/policy0/scaling_available_frequencies
408000 600000 816000 1008000 1200000 1416000 1608000 1704000
# Fix the CPU frequency, e.g., fix at 1.7GHz
echo userspace > /sys/devices/system/cpu/cpufreq/policy0/scaling_governor
echo 1704000 > /sys/devices/system/cpu/cpufreq/policy0/scaling_setspeed
```

2. DDR related commands

(1) Query the frequency of DDR

```
cat /sys/class/devfreq/dmc/cur_freq
or
cat /sys/kernel/debug/clk/clk_summary | grep ddr
```

(2) Fix the frequency of DDR (Need extra firmware)

```
# Query the avilable frequency of DDR
cat /sys/class/devfreq/dmc/available_frequencies
# Fix the frequency of DDR, e.g., at 1560MHz
echo userspace > /sys/class/devfreq/dmc/governor
echo 1560000000 > /sys/class/devfreq/dmc/userspace/set_freq
```

3. NPU related commands

(1) Query the frequency of NPU:

For RK356X:

```
cat /sys/kernel/debug/clk/clk_summary | grep npu
or
cat /sys/class/devfreq/fde40000.npu/cur_freq
```

For RK3588 (**Need to upgrade firmware**):

```
cat /sys/class/devfreq/fdab0000.npu/cur_freq
```

For RV1106/RV1103:

```
cat /sys/kernel/debug/clk/clk_summary | grep npu
```

(2) **Fix the frequency of NPU：**

Note: The driver version after 0.7.2, it is required to turn on the power of NPU first before setting frequency.

For RK356X:

```
# Query the available frequency of NPU
cat /sys/class/devfreq/fde40000.npu/available_frequencies
# Fix NPU frequency，e.g., fix at 1 GHz
echo userspace > /sys/class/devfreq/fde40000.npu/governor
echo 1000000000 > /sys/kernel/debug/clk/clk_scmi_npu/clk_rate
```

For RK3588 **(Need to upgrade firmware)** :

```
# Query the available frequency of NPU
cat /sys/class/devfreq/ fdab0000.npu/available_frequencies
# Fix the NPU frequency, e.g., at 1GHz
echo userspace > /sys/class/devfreq/fdab0000.npu/governor
echo 1000000000 > /sys/kernel/debug/clk/clk_npu_dsu0/clk_rate
```

For RV1106/RV1103 **(Unsupported)**

4.6.4 NPU supports query settings

If the NPU driver version is after 0.7.2, you can query the NPU version, the utilization of different NPU cores and manually switch the NPU power supply through the node.

（1）query NPU driver version

```
cat /sys/kernel/debug/rknpu/driver_version
or
cat /proc/debug/rknpu/driver_version
```

（2）query NPU utilization

```
cat /sys/kernel/debug/rknpu/load
or
cat /proc/debug/rknpu/load
```

（3）query NPU power status

```
cat /sys/kernel/debug/rknpu/power
```

（4）open NPU power

```
echo on > /sys/kernel/debug/rknpu/power
```

（5）close NPU power

```
echo off > /sys/kernel/debug/rknpu/power
```

There are some new functions after driver version 0.8.2 shown below.

（1）query NPU frequency

```
cat /sys/kernel/debug/rknpu/freq
```

（2）Setting up NPU frequency

```
# using RK3588 as an example
# look up available frequency of NPU
cat /sys/class/devfreq/ fdab0000.npu/available_frequencies
# Fix NPU frequency, for example, 1GHz
echo 1000000000 > /sys/kernel/debug/rknpu/freq
```

（3）query NPU voltage status

```
cat /sys/kernel/debug/rknpu/volt
```

（4）query NPU delay time of power during shutdown (unit: ms)

```
cat /sys/kernel/debug/rknpu/delayms
```

（5）Setting up delay time of power during shutdown for NPU Power (unit: ms)

```
echo 2000 > /sys/kernel/debug/rknpu/delayms
```