原 # FFmpeg与libx264接口源代码简单分析

2015年05月25日 01:48:07 阅读数：17416

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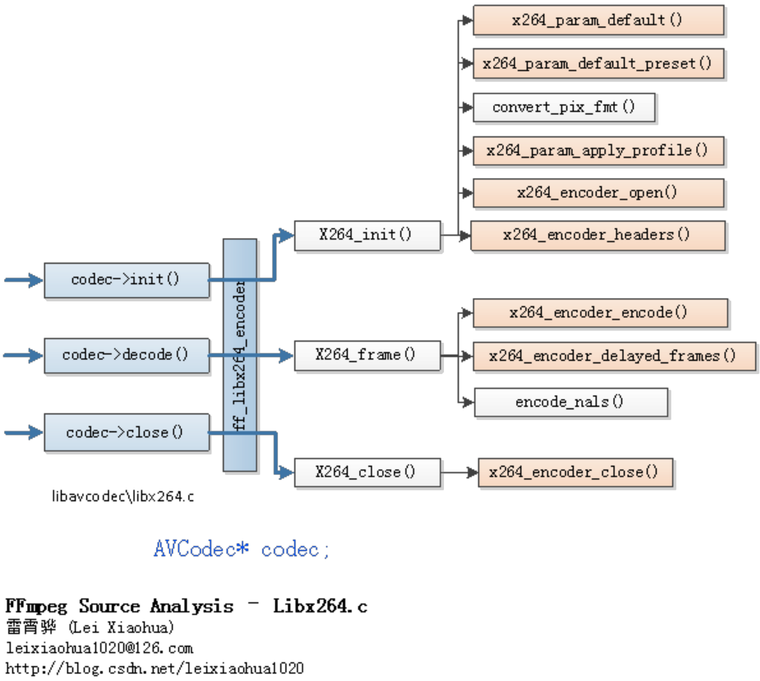
本文简单记录一下FFmpeg的libavcodec中与libx264接口部分的源代码。该部分源代码位于“libavcodec/libx264.c”中。正是有了这部分代码，使得FFmpeg可以调用libx264编码H.264视频。

函数调用关系图

FFmpeg的libavcodec中的libx264.c的函数调用关系如下图所示。



从图中可以看出，libx264对应的AVCodec结构体ff_libx264_encoder中设定编码器初始化函数是X264_init()，编码一帧数据的函数是X264_frame()，编码器关闭函数是X264_close()。

X264_init()调用了如下函数：

[libx264 API] x264_param_default()：设置默认参数。

[libx264 API] x264_param_default_preset()：设置默认preset。

convert_pix_fmt()：将FFmpeg像素格式转换为libx264像素格式。

[libx264 API] x264_param_apply_profile()：设置Profile。

[libx264 API] x264_encoder_open()：打开编码器。

[libx264 API] x264_encoder_headers()：需要全局头的时候，输出头信息。

X264_frame()调用了如下函数：

[libx264 API] x264_encoder_encode()：编码一帧数据。

[libx264 API] x264_encoder_delayed_frames()：输出编码器中缓存的数据。

encode_nals()：将编码后得到的x264_nal_t转换为AVPacket。

X264_close()调用了如下函数：

[libx264 API] x264_encoder_close()：关闭编码器。

下文将会分别分析X264_init()，X264_frame()和X264_close()这三个函数。

ff_libx264_encoder

ff_libx264_encoder是libx264对应的AVCodec结构体，定义如下所示。

[cpp]

```cpp
//libx264对应的AVCodec结构体
AVCodec ff_libx264_encoder = {
    .name             = "libx264",
    .long_name        = NULL_IF_CONFIG_SMALL("libx264 H.264 / AVC / MPEG-4 AVC / MPEG-4 part 10"),
    .type             = AVMEDIA_TYPE_VIDEO,
    .id               = AV_CODEC_ID_H264,
    .priv_data_size   = sizeof(X264Context),
    .init             = X264_init,
    .encode2          = X264_frame,
    .close            = X264_close,
    .capabilities     = CODEC_CAP_DELAY | CODEC_CAP_AUTO_THREADS,
    .priv_class       = &x264_class,
    .defaults         = x264_defaults,
    .init_static_data = X264_init_static,
};
```

从ff_libx264_encoder定义中可以看出：init()指向X264_init()，encode2()指向 X264_frame()， close()指向 X264_close()。此外priv_class指向一个x264_class静态结构体，该结构体是libx264对应的AVClass，定义如下。

[cpp]

```cpp
static const AVClass x264_class = {
    .class_name = "libx264",
    .item_name  = av_default_item_name,
    .option     = options,//选项
    .version    = LIBAVUTIL_VERSION_INT,
};
```

x264_class中的option指向一个options[]静态数组，其中包含了libx264支持的AVOption选项，如下所示。

[cpp]

```cpp
//FFmpeg针对libx264提供的可以通过AVOption设置的选项
#define OFFSET(x) offsetof(X264Context, x)
#define VE AV_OPT_FLAG_VIDEO_PARAM | AV_OPT_FLAG_ENCODING_PARAM
static const AVOption options[] = {
    { "preset",        "Set the encoding preset (cf. x264 --fullhelp)",   OFFSET(preset),        AV_OPT_TYPE_STRING, { .str = "medium" }, 0, 0, VE},
    { "tune",          "Tune the encoding params (cf. x264 --fullhelp)",  OFFSET(tune),          AV_OPT_TYPE_STRING, { 0 }, 0, 0, VE},
    { "profile",       "Set profile restrictions (cf. x264 --fullhelp) ", OFFSET(profile),       AV_OPT_TYPE_STRING, { 0 }, 0, 0, VE},
    { "fastfirstpass", "Use fast settings when encoding first pass",      OFFSET(fastfirstpass), AV_OPT_TYPE_INT,    { .i64 = 1 }, 0, 1, VE},
    {"level", "Specify level (as defined by Annex A)", OFFSET(level), AV_OPT_TYPE_STRING, {.str=NULL}, 0, 0, VE},
    {"passlogfile", "Filename for 2 pass stats", OFFSET(stats), AV_OPT_TYPE_STRING, {.str=NULL}, 0, 0, VE},
    {"wpredp", "Weighted prediction for P-frames", OFFSET(wpredp), AV_OPT_TYPE_STRING, {.str=NULL}, 0, 0, VE},
    {"x264opts", "x264 options", OFFSET(x264opts), AV_OPT_TYPE_STRING, {.str=NULL}, 0, 0, VE},
    { "crf",           "Select the quality for constant quality mode",    OFFSET(crf),           AV_OPT_TYPE_FLOAT,  {.dbl = -1 }, -1, FLT_MAX, VE },
    { "crf_max",       "In CRF mode, prevents VBV from lowering quality beyond this point.",OFFSET(crf_max), AV_OPT_TYPE_FLOAT, {.dbl = -1 }, -1, FLT_MAX, VE },
    { "qp",            "Constant quantization parameter rate control method",OFFSET(cqp),        AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE },
    { "aq-mode",       "AQ method",                                       OFFSET(aq_mode),       AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE, "aq_mode"},
    { "none",          NULL,                              0, AV_OPT_TYPE_CONST, {.i64 = X264_AQ_NONE},         INT_MIN, INT_MAX, VE, "aq_mode" },
    { "variance",      "Variance AQ (complexity mask)",   0, AV_OPT_TYPE_CONST, {.i64 = X264_AQ_VARIANCE},     INT_MIN, INT_MAX, VE, "aq_mode" },
    { "autovariance",  "Auto-variance AQ (experimental)", 0, AV_OPT_TYPE_CONST, {.i64 = X264_AQ_AUTOVARIANCE}, INT_MIN, INT_MAX, VE, "aq_mode" },
    { "aq-strength",   "AQ strength. Reduces blocking and blurring in flat and textured areas.", OFFSET(aq_strength), AV_OPT_TYPE_FLOAT, {.dbl = -1}, -1, FLT_MAX, VE},
    { "psy",           "Use psychovisual optimizations.",                 OFFSET(psy),           AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE },
    { "psy-rd",        "Strength of psychovisual optimization, in <psy-rd>:<psy-trellis> format.", OFFSET(psy_rd), AV_OPT_TYPE_STRING,  {0 }, 0, 0, VE},
    { "rc-lookahead",  "Number of frames to look ahead for frametype and ratecontrol", OFFSET(rc_lookahead), AV_OPT_TYPE_INT, { .i64 = -1 }, -1, INT_MAX, VE },
    { "weightb",       "Weighted prediction for B-frames.",               OFFSET(weightb),       AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE },
    { "weightp",       "Weighted prediction analysis method.",            OFFSET(weightp),       AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE, "weightp" },
    { "none",          NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_WEIGHTP_NONE},   INT_MIN, INT_MAX, VE, "weightp" },
    { "simple",        NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_WEIGHTP_SIMPLE}, INT_MIN, INT_MAX, VE, "weightp" },
    { "smart",         NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_WEIGHTP_SMART},  INT_MIN, INT_MAX, VE, "weightp" },
    { "ssim",          "Calculate and print SSIM stats.",                 OFFSET(ssim),          AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE },
    { "intra-refresh", "Use Periodic Intra Refresh instead of IDR frames.",OFFSET(intra_refresh),AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE },
    { "bluray-compat", "Bluray compatibility workarounds.",               OFFSET(bluray_compat) ,AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE },
    { "b-bias",        "Influences how often B-frames are used",          OFFSET(b_bias),        AV_OPT_TYPE_INT,    { .i64 = INT_MIN}, INT_MIN, INT_MAX, VE },
    { "b-pyramid",     "Keep some B-frames as references.",               OFFSET(b_pyramid),     AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE, "b_pyramid" },
    { "none",          NULL,                                  0, AV_OPT_TYPE_CONST, {.i64 = X264_B_PYRAMID_NONE},   INT_MIN, INT_MAX, , "b_pyramid" },
    { "strict",        "Strictly hierarchical pyramid",       0, AV_OPT_TYPE_CONST, {.i64 = X264_B_PYRAMID_STRICT}, INT_MIN, INT_MAX, VE, "b_pyramid" },
    { "normal",        "Non-strict (not Blu-ray compatible)", 0, AV_OPT_TYPE_CONST, {.i64 = X264_B_PYRAMID_NORMAL}, INT_MIN, INT_MAX, VE, "b_pyramid" },
    { "mixed-refs",    "One reference per partition, as opposed to one reference per macroblock", OFFSET(mixed_refs), AV_OPT_TYPE_INT, { .i64 = -1}, -1, 1, VE },
    { "8x8dct",        "High profile 8x8 transform.",                     OFFSET(dct8x8),        AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE},
    { "fast-pskip",    NULL,                                              OFFSET(fast_pskip),    AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE},
    { "aud",           "Use access unit delimiters.",                     OFFSET(aud),           AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE},
    { "mbtree",        "Use macroblock tree ratecontrol.",                OFFSET(mbtree),        AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, 1, VE},
    { "deblock",       "Loop filter parameters, in <alpha:beta> form.",   OFFSET(deblock),       AV_OPT_TYPE_STRING, { 0 },  0, 0, VE},
    { "cplxblur",      "Reduce fluctuations in QP (before curve compression)", OFFSET(cplxblur), AV_OPT_TYPE_FLOAT,  {.dbl = -1 }, -1, FLT_MAX, VE},
1, FLT_MAX, VE},
    { "partitions",    "A comma-separated list of partitions to consider. "
                       "Possible values: p8x8, p4x4, b8x8, i8x8, i4x4, none, all", OFFSET(partitions), AV_OPT_TYPE_STRING, { 0 }, 0, 0, VE},
    { "direct-pred",   "Direct MV prediction mode",                        OFFSET(direct_pred),   AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE, "direct-pred" },
    { "none",          NULL,      0,    AV_OPT_TYPE_CONST, { .i64 = X264_DIRECT_PRED_NONE },     0, 0, VE, "direct-pred" },
    { "spatial",       NULL,      0,    AV_OPT_TYPE_CONST, { .i64 = X264_DIRECT_PRED_SPATIAL },  0, 0, VE, "direct-pred" },
    { "temporal",      NULL,      0,    AV_OPT_TYPE_CONST, { .i64 = X264_DIRECT_PRED_TEMPORAL }, 0, 0, VE, "direct-pred" },
    { "auto",          NULL,      0,    AV_OPT_TYPE_CONST, { .i64 = X264_DIRECT_PRED_AUTO },     0, 0, VE, "direct-pred" },
    { "slice-max-size","Limit the size of each slice in bytes",            OFFSET(slice_max_size),AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE },
    { "stats",         "Filename for 2 pass stats",                        OFFSET(stats),         AV_OPT_TYPE_STRING, { 0 },  0, 0, VE },
    { "nal-hrd",       "Signal HRD information (requires vbv-bufsize; "
                       "cbr not allowed in .mp4)",                         OFFSET(nal_hrd),       AV_OPT_TYPE_INT,    { .i64 = -1 }, -1, INT_MAX, VE, "nal-hrd" },
    { "none",          NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_NAL_HRD_NONE}, INT_MIN, INT_MAX, VE, "nal-hrd" },
    { "vbr",           NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_NAL_HRD_VBR},  INT_MIN, INT_MAX, VE, "nal-hrd" },
    { "cbr",           NULL, 0, AV_OPT_TYPE_CONST, {.i64 = X264_NAL_HRD_CBR},  INT_MIN, INT_MAX, VE, "nal-hrd" },
    { "avcintra-class","AVC-Intra class 50/100/200",                       OFFSET(avcintra_class),AV_OPT_TYPE_INT,     { .i64 = -1 }, -1, 200   , VE},
    { "x264-params",  "Override the x264 configuration using a :-separated list of key=value parameters", OFFSET(x264_params), AV_OPT_TYPE_STRING, { 0 }, 0, 0, VE },
    { NULL },
};
```

options[]数组中包含的选项支持在FFmpeg中通过AVOption进行设置。

X264_init()

X264_init()用于初始化libx264编码器。该函数的定义如下所示。

[cpp]

```
//libx264编码器初始化
static av_cold int X264_init(AVCodecContext *avctx)
{
    //FFmpeg中针对libx264的私有结构体
    X264Context *x4 = avctx->priv_data;
    int sw,sh;

    if (avctx->global_quality > 0)
        av_log(avctx, AV_LOG_WARNING, "-qscale is ignored, -crf is recommended.\n");

    //[libx264 API] 设置默认参数
    x264_param_default(&x4->params);

    x4->params.b_deblocking_filter         = avctx->flags & CODEC_FLAG_LOOP_FILTER;

    if (x4->preset || x4->tune)
        if (x264_param_default_preset(&x4->params, x4->preset, x4->tune) < 0) {  //[libx264 API] 设置preset
            int i;
            av_log(avctx, AV_LOG_ERROR, "Error setting preset/tune %s/%s.\n", x4->preset, x4->tune);
            av_log(avctx, AV_LOG_INFO, "Possible presets:");
            for (i = 0; x264_preset_names[i]; i++)
                av_log(avctx, AV_LOG_INFO, " %s", x264_preset_names[i]);
            av_log(avctx, AV_LOG_INFO, "\n");
            av_log(avctx, AV_LOG_INFO, "Possible tunes:");
            for (i = 0; x264_tune_names[i]; i++)
                av_log(avctx, AV_LOG_INFO, " %s", x264_tune_names[i]);
            av_log(avctx, AV_LOG_INFO, "\n");
            return AVERROR(EINVAL);
        }

    if (avctx->level > 0)
        x4->params.i_level_idc = avctx->level;
    //libx264日志输出设置为FFmpeg的日志输出
    x4->params.pf_log               = X264_log;
    x4->params.p_log_private        = avctx;
    x4->params.i_log_level          = X264_LOG_DEBUG;
    //FFmpeg像素格式映射到libx264
    x4->params.i_csp                = convert_pix_fmt(avctx->pix_fmt);

    OPT_STR("weightp", x4->wpredp);

    //FFmpeg码率映射到libx264
    if (avctx->bit_rate) {
        x4->params.rc.i_bitrate   = avctx->bit_rate / 1000;
        x4->params.rc.i_rc_method = X264_RC_ABR;
    }
    x4->params.rc.i_vbv_buffer_size = avctx->rc_buffer_size / 1000;
    x4->params.rc.i_vbv_max_bitrate = avctx->rc_max_rate    / 1000;
    x4->params.rc.b_stat_write      = avctx->flags & CODEC_FLAG_PASS1;
    if (avctx->flags & CODEC_FLAG_PASS2) {
        x4->params.rc.b_stat_read = 1;
    } else {
        if (x4->crf >= 0) {
            x4->params.rc.i_rc_method   = X264_RC_CRF;
            x4->params.rc.f_rf_constant = x4->crf;
        } else if (x4->cqp >= 0) {
            x4->params.rc.i_rc_method   = X264_RC_CQP;
            x4->params.rc.i_qp_constant = x4->cqp;
        }

        if (x4->crf_max >= 0)
            x4->params.rc.f_rf_constant_max = x4->crf_max;
    }

    if (avctx->rc_buffer_size && avctx->rc_initial_buffer_occupancy > 0 &&
        (avctx->rc_initial_buffer_occupancy <= avctx->rc_buffer_size)) {
        x4->params.rc.f_vbv_buffer_init =
            (float)avctx->rc_initial_buffer_occupancy / avctx->rc_buffer_size;
    }

    OPT_STR("level", x4->level);

    if (avctx->i_quant_factor > 0)
        x4->params.rc.f_ip_factor         = 1 / fabs(avctx->i_quant_factor);
    if (avctx->b_quant_factor > 0)
        x4->params.rc.f_pb_factor         = avctx->b_quant_factor;
    if (avctx->chromaoffset)
        x4->params.analyse.i_chroma_qp_offset = avctx->chromaoffset;
    //FFmpeg运动估计方法映射到libx264
    if (avctx->me_method == ME_EPZS)
        x4->params.analyse.i_me_method = X264_ME_DIA;
    else if (avctx->me_method == ME_HEX)
        x4->params.analyse.i_me_method = X264_ME_HEX;
    else if (avctx->me_method == ME_UMH)
        x4->params.analyse.i_me_method = X264_ME_UMH;
    else if (avctx->me_method == ME_FULL)
        x4->params.analyse.i_me_method = X264_ME_ESA;
    else if (avctx->me_method == ME_TESA)
        x4->params.analyse.i_me_method = X264_ME_TESA;

    //把AVCodecContext的值（主要是编码时候的一些通用选项）映射到x264_param_t
    if (avctx->gop_size >= 0)
        x4->params.i_keyint_max         = avctx->gop_size;
    if (avctx->max_b_frames >= 0)
        x4->params.i_bframe             = avctx->max_b_frames;
    if (avctx->scenechange_threshold >= 0)
        x4->params.i_scenecut_threshold = avctx->scenechange_threshold;
    if (avctx->qmin >= 0)
        x4->params.rc.i_qp_min          = avctx->qmin;
    if (avctx->qmax >= 0)
        x4->params.rc.i_qp_max          = avctx->qmax;
    if (avctx->max_qdiff >= 0)
        x4->params.rc.i_qp_step         = avctx->max_qdiff;
    if (avctx->qblur >= 0)
        x4->params.rc.f_qblur           = avctx->qblur;     /* temporally blur quants */
    if (avctx->qcompress >= 0)
        x4->params.rc.f_qcompress       = avctx->qcompress; /* 0.0 => cbr, 1.0 => constant qp */
    if (avctx->refs >= 0)
        x4->params.i_frame_reference    = avctx->refs;
    else if (x4->level) {
        int i;
        int mbn = FF_CEIL_RSHIFT(avctx->width, 4) * FF_CEIL_RSHIFT(avctx->height, 4);
        int level_id = -1;
        char *tail;
        int scale = X264_BUILD < 129 ? 384 : 1;

        if (!strcmp(x4->level, "1b")) {
            level_id = 9;
        } else if (strlen(x4->level) <= 3){
            level_id = av_strtod(x4->level, &tail) * 10 + 0.5;
            if (*tail)
                level_id = -1;
        }
        if (level_id <= 0)
            av_log(avctx, AV_LOG_WARNING, "Failed to parse level\n");

        for (i = 0; i<x264_levels[i].level_idc; i++)
            if (x264_levels[i].level_idc == level_id)
                x4->params.i_frame_reference = av_clip(x264_levels[i].dpb / mbn / scale, 1, x4->params.i_frame_reference);
    }

    if (avctx->trellis >= 0)
        x4->params.analyse.i_trellis    = avctx->trellis;
    if (avctx->me_range >= 0)
        x4->params.analyse.i_me_range   = avctx->me_range;
    if (avctx->noise_reduction >= 0)
        x4->params.analyse.i_noise_reduction = avctx->noise_reduction;
    if (avctx->me_subpel_quality >= 0)
        x4->params.analyse.i_subpel_refine   = avctx->me_subpel_quality;
    if (avctx->b_frame_strategy >= 0)
        x4->params.i_bframe_adaptive = avctx->b_frame_strategy;
    if (avctx->keyint_min >= 0)
        x4->params.i_keyint_min = avctx->keyint_min;
    if (avctx->coder_type >= 0)
```

```
        x4->params.b_cabac = avctx->coder_type == FF_CODER_TYPE_AC;
    if (avctx->me_cmp >= 0)
        x4->params.analyse.b_chroma_me = avctx->me_cmp & FF_CMP_CHROMA;

    //把X264Context中的信息（主要是针对于libx264的一些选项）映射到x264_param_t
    if (x4->aq_mode >= 0)
        x4->params.rc.i_aq_mode = x4->aq_mode;
    if (x4->aq_strength >= 0)
        x4->params.rc.f_aq_strength = x4->aq_strength;
    PARSE_X264_OPT("psy-rd", psy_rd);
    PARSE_X264_OPT("deblock", deblock);
    PARSE_X264_OPT("partitions", partitions);
    PARSE_X264_OPT("stats", stats);
    if (x4->psy >= 0)
        x4->params.analyse.b_psy  = x4->psy;
    if (x4->rc_lookahead >= 0)
        x4->params.rc.i_lookahead = x4->rc_lookahead;
    if (x4->weightp >= 0)
        x4->params.analyse.i_weighted_pred = x4->weightp;
    if (x4->weightb >= 0)
        x4->params.analyse.b_weighted_bipred = x4->weightb;
    if (x4->cplxblur >= 0)
        x4->params.rc.f_complexity_blur = x4->cplxblur;

    if (x4->ssim >= 0)
        x4->params.analyse.b_ssim = x4->ssim;
    if (x4->intra_refresh >= 0)
        x4->params.b_intra_refresh = x4->intra_refresh;
    if (x4->bluray_compat >= 0) {
        x4->params.b_bluray_compat = x4->bluray_compat;
        x4->params.b_vfr_input = 0;
    }
    if (x4->avcintra_class >= 0)
#if X264_BUILD >= 142
        x4->params.i_avcintra_class = x4->avcintra_class;
#else
        av_log(avctx, AV_LOG_ERROR,
               "x264 too old for AVC Intra, at least version 142 needed\n");
#endif
    if (x4->b_bias != INT_MIN)
        x4->params.i_bframe_bias              = x4->b_bias;
    if (x4->b_pyramid >= 0)
        x4->params.i_bframe_pyramid = x4->b_pyramid;
    if (x4->mixed_refs >= 0)
        x4->params.analyse.b_mixed_references = x4->mixed_refs;
    if (x4->dct8x8 >= 0)
        x4->params.analyse.b_transform_8x8    = x4->dct8x8;
    if (x4->fast_pskip >= 0)
        x4->params.analyse.b_fast_pskip       = x4->fast_pskip;
    if (x4->aud >= 0)
        x4->params.b_aud                      = x4->aud;
    if (x4->mbtree >= 0)
        x4->params.rc.b_mb_tree               = x4->mbtree;
    if (x4->direct_pred >= 0)
        x4->params.analyse.i_direct_mv_pred   = x4->direct_pred;

    if (x4->slice_max_size >= 0)
        x4->params.i_slice_max_size =  x4->slice_max_size;
    else {
        /*
         * Allow x264 to be instructed through AVCodecContext about the maximum
         * size of the RTP payload. For example, this enables the production of
         * payload suitable for the H.264 RTP packetization-mode 0 i.e. single
         * NAL unit per RTP packet.
         */
        if (avctx->rtp_payload_size)
            x4->params.i_slice_max_size = avctx->rtp_payload_size;
    }

    if (x4->fastfirstpass)
        x264_param_apply_fastfirstpass(&x4->params);

    /* Allow specifying the x264 profile through AVCodecContext. */
    //设置Profile
    if (!x4->profile)
        switch (avctx->profile) {
        case FF_PROFILE_H264_BASELINE:
            x4->profile = av_strdup("baseline");
            break;
        case FF_PROFILE_H264_HIGH:
            x4->profile = av_strdup("high");
            break;
        case FF_PROFILE_H264_HIGH_10:
            x4->profile = av_strdup("high10");
            break;
        case FF_PROFILE_H264_HIGH_422:
            x4->profile = av_strdup("high422");
            break;
        case FF_PROFILE_H264_HIGH_444:
            x4->profile = av_strdup("high444");
            break;
        case FF_PROFILE_H264_MAIN:
            x4->profile = av_strdup("main");
            break;
        default:
            break;
        }

    if (x4->nal_hrd >= 0)
        x4->params.i_nal_hrd = x4->nal_hrd;
    //
    if (x4->profile)
        if (x264_param_apply_profile(&x4->params, x4->profile) < 0) {
            int i;
            av_log(avctx, AV_LOG_ERROR, "Error setting profile %s.\n", x4->profile);
            av_log(avctx, AV_LOG_INFO, "Possible profiles:");
            for (i = 0; x264_profile_names[i]; i++)
                av_log(avctx, AV_LOG_INFO, " %s", x264_profile_names[i]);
            av_log(avctx, AV_LOG_INFO, "\n");
            return AVERROR(EINVAL);
        }
    //宽高，帧率等
    x4->params.i_width          = avctx->width;
    x4->params.i_height         = avctx->height;
    av_reduce(&sw, &sh, avctx->sample_aspect_ratio.num, avctx->sample_aspect_ratio.den, 4096);
    x4->params.vui.i_sar_width  = sw;
    x4->params.vui.i_sar_height = sh;
    x4->params.i_timebase_den = avctx->time_base.den;
    x4->params.i_timebase_num = avctx->time_base.num;
    x4->params.i_fps_num = avctx->time_base.den;
    x4->params.i_fps_den = avctx->time_base.num * avctx->ticks_per_frame;

    x4->params.analyse.b_psnr = avctx->flags & CODEC_FLAG_PSNR;

    x4->params.i_threads      = avctx->thread_count;
    if (avctx->thread_type)
        x4->params.b_sliced_threads = avctx->thread_type == FF_THREAD_SLICE;

    x4->params.b_interlaced   = avctx->flags & CODEC_FLAG_INTERLACED_DCT;

    x4->params.b_open_gop     = !(avctx->flags & CODEC_FLAG_CLOSED_GOP);

    x4->params.i_slice_count  = avctx->slices;

    x4->params.vui.b_fullrange = avctx->pix_fmt == AV_PIX_FMT_YUVJ420P ||
                                 avctx->pix_fmt == AV_PIX_FMT_YUVJ422P ||
                                 avctx->pix_fmt == AV_PIX_FMT_YUVJ444P ||
                                 avctx->color_range == AVCOL_RANGE_JPEG;

    if (avctx->colorspace != AVCOL_SPC_UNSPECIFIED)
        x4->params.vui.i_colmatrix = avctx->colorspace;
    if (avctx->color_primaries != AVCOL_PRI_UNSPECIFIED)
        x4->params.vui.i_colorprim = avctx->color_primaries;
    if (avctx->color_trc != AVCOL_TRC_UNSPECIFIED)
        x4->params.vui.i_transfer  = avctx->color_trc;

    if (avctx->flags & CODEC_FLAG_GLOBAL_HEADER)
        x4->params.b_repeat_headers = 0;

    if(x4->x264opts){
        const char *p= x4->x264opts;
        while(p){
            char param[256]={0}, val[256]={0};
            if(sscanf(p, "%255[^:=]=%255[^:]", param, val) == 1){
                OPT_STR(param, "1");
            }else
                OPT_STR(param, val);
            p= strchr(p, ':');
            p+=!!p;
        }
    }

    if (x4->x264_params) {
        AVDictionary *dict    = NULL;
        AVDictionaryEntry *en = NULL;

        if (!av_dict_parse_string(&dict, x4->x264_params, "=", ":", 0)) {
            while ((en = av_dict_get(dict, "", en, AV_DICT_IGNORE_SUFFIX))) {
                if (x264_param_parse(&x4->params, en->key, en->value) < 0)
                    av_log(avctx, AV_LOG_WARNING,
                           "Error parsing option '%s = %s'.\n",
                            en->key, en->value);
            }

            av_dict_free(&dict);
        }
    }

    // update AVCodecContext with x264 parameters
    avctx->has_b_frames = x4->params.i_bframe ?
        x4->params.i_bframe_pyramid ? 2 : 1 : 0;
    if (avctx->max_b_frames < 0)
        avctx->max_b_frames = 0;
```

```cpp
        avctx->max_b_frames = 0;

    avctx->bit_rate = x4->params.rc.i_bitrate*1000;

    //------------------------
    //设置完参数后，打开编码器
    x4->enc = x264_encoder_open(&x4->params);
    if (!x4->enc)
        return -1;

    avctx->coded_frame = av_frame_alloc();
    if (!avctx->coded_frame)
        return AVERROR(ENOMEM);
    //如果需要全局头
    if (avctx->flags & CODEC_FLAG_GLOBAL_HEADER) {
        x264_nal_t *nal;
        uint8_t *p;
        int nnal, s, i;

        s = x264_encoder_headers(x4->enc, &nal, &nnal);
        avctx->extradata = p = av_malloc(s);

        for (i = 0; i < nnal; i++) {
            /* Don't put the SEI in extradata. */
            if (nal[i].i_type == NAL_SEI) {
                av_log(avctx, AV_LOG_INFO, "%s\n", nal[i].p_payload+25);
                x4->sei_size = nal[i].i_payload;
                x4->sei      = av_malloc(x4->sei_size);
                memcpy(x4->sei, nal[i].p_payload, nal[i].i_payload);
                continue;
            }
            memcpy(p, nal[i].p_payload, nal[i].i_payload);
            p += nal[i].i_payload;
        }
        avctx->extradata_size = p - avctx->extradata;
    }

    return 0;
}
```

从源代码可以看出，X264_init()主要将各种选项值传递给libx264。这些选项有两个来源：AVCodecContext和X264Context。AVCodecContext中包含了编码器的一些通用选项，而X264Context包含了一些libx264特有的选项。在这里需要注意，FFmpeg中的一些选项的单位和libx264中对应选项的单位是不一样的，因此需要做一些转换。例如像素格式的转换函数convert_pix_fmt()就是完成了这个功能。该函数的定义如下所示。

[cpp]

```cpp
//映射FFmpeg和libx264的像素格式
static int convert_pix_fmt(enum AVPixelFormat pix_fmt)
{
    switch (pix_fmt) {
    case AV_PIX_FMT_YUV420P:
    case AV_PIX_FMT_YUVJ420P:
    case AV_PIX_FMT_YUV420P9:
    case AV_PIX_FMT_YUV420P10: return X264_CSP_I420;
    case AV_PIX_FMT_YUV422P:
    case AV_PIX_FMT_YUVJ422P:
    case AV_PIX_FMT_YUV422P10: return X264_CSP_I422;
    case AV_PIX_FMT_YUV444P:
    case AV_PIX_FMT_YUVJ444P:
    case AV_PIX_FMT_YUV444P9:
    case AV_PIX_FMT_YUV444P10: return X264_CSP_I444;
#ifdef X264_CSP_BGR
    case AV_PIX_FMT_BGR24:
        return X264_CSP_BGR;

    case AV_PIX_FMT_RGB24:
        return X264_CSP_RGB;
#endif
    case AV_PIX_FMT_NV12:      return X264_CSP_NV12;
    case AV_PIX_FMT_NV16:
    case AV_PIX_FMT_NV20:      return X264_CSP_NV16;
    };
    return 0;
}
```

可以看出convert_pix_fmt()将AV_PIX_FMT_XXX转换成了X264_CSP_XXX。
在一切参数设置完毕后，X264_init()会调用x264_encoder_open()打开编码器，完成初始化工作。

X264_frame()

X264_frame()用于编码一帧视频数据。该函数的定义如下所示。

[cpp]

```cpp
//libx264编码1帧数据
//
// AVFrame --> x264_picture_t --> x264_nal_t --> AVPacket
```

```
//
static int X264_frame(AVCodecContext *ctx, AVPacket *pkt, const AVFrame *frame,
                      int *got_packet)
{
    X264Context *x4 = ctx->priv_data;
    x264_nal_t *nal;
    int nnal, i, ret;
    x264_picture_t pic_out = {0};
    AVFrameSideData *side_data;

    x264_picture_init( &x4->pic );
    x4->pic.img.i_csp   = x4->params.i_csp;
    if (x264_bit_depth > 8)
        x4->pic.img.i_csp |= X264_CSP_HIGH_DEPTH;
    x4->pic.img.i_plane = avfmt2_num_planes(ctx->pix_fmt);

    if (frame) {
        //将AVFrame中的数据赋值给x264_picture_t
        //
        // AVFrame --> x264_picture_t
        //
        for (i = 0; i < x4->pic.img.i_plane; i++) {
            x4->pic.img.plane[i]    = frame->data[i];
            x4->pic.img.i_stride[i] = frame->linesize[i];
        }

        x4->pic.i_pts  = frame->pts;
        //设置帧类型
        x4->pic.i_type =
            frame->pict_type == AV_PICTURE_TYPE_I ? X264_TYPE_KEYFRAME :
            frame->pict_type == AV_PICTURE_TYPE_P ? X264_TYPE_P :
            frame->pict_type == AV_PICTURE_TYPE_B ? X264_TYPE_B :
                                            X264_TYPE_AUTO;
        //检查参数设置是否正确，不正确就重新设置
        if (x4->avcintra_class < 0) {
        if (x4->params.b_interlaced && x4->params.b_tff != frame->top_field_first) {
            x4->params.b_tff = frame->top_field_first;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }
        if (x4->params.vui.i_sar_height != ctx->sample_aspect_ratio.den ||
            x4->params.vui.i_sar_width  != ctx->sample_aspect_ratio.num) {
            x4->params.vui.i_sar_height = ctx->sample_aspect_ratio.den;
            x4->params.vui.i_sar_width  = ctx->sample_aspect_ratio.num;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }

        if (x4->params.rc.i_vbv_buffer_size != ctx->rc_buffer_size / 1000 ||
            x4->params.rc.i_vbv_max_bitrate != ctx->rc_max_rate    / 1000) {
            x4->params.rc.i_vbv_buffer_size = ctx->rc_buffer_size / 1000;
            x4->params.rc.i_vbv_max_bitrate = ctx->rc_max_rate    / 1000;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }

        if (x4->params.rc.i_rc_method == X264_RC_ABR &&
            x4->params.rc.i_bitrate != ctx->bit_rate / 1000) {
            x4->params.rc.i_bitrate = ctx->bit_rate / 1000;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }

        if (x4->crf >= 0 &&
            x4->params.rc.i_rc_method == X264_RC_CRF &&
            x4->params.rc.f_rf_constant != x4->crf) {
            x4->params.rc.f_rf_constant = x4->crf;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }

        if (x4->params.rc.i_rc_method == X264_RC_CQP &&
            x4->cqp >= 0 &&
            x4->params.rc.i_qp_constant != x4->cqp) {
            x4->params.rc.i_qp_constant = x4->cqp;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }

        if (x4->crf_max >= 0 &&
            x4->params.rc.f_rf_constant_max != x4->crf_max) {
            x4->params.rc.f_rf_constant_max = x4->crf_max;
            x264_encoder_reconfig(x4->enc, &x4->params);
        }
        }

        side_data = av_frame_get_side_data(frame, AV_FRAME_DATA_STEREO3D);
        if (side_data) {
            AVStereo3D *stereo = (AVStereo3D *)side_data->data;
            int fpa_type;

            switch (stereo->type) {
            case AV_STEREO3D_CHECKERBOARD:
                fpa_type = 0;
                break;
            case AV_STEREO3D_COLUMNS:
                fpa_type = 1;
                break;
            case AV_STEREO3D_LINES:
                fpa_type = 2;
                break;
            case AV_STEREO3D_SIDEBYSIDE:
                fpa_type = 3;
                break;
            case AV_STEREO3D_TOPBOTTOM:
                fpa_type = 4;
                break;
            case AV_STEREO3D_FRAMESEQUENCE:
                fpa_type = 5;
                break;
            default:
                fpa_type = -1;
                break;
            }

            if (fpa_type != x4->params.i_frame_packing) {
                x4->params.i_frame_packing = fpa_type;
                x264_encoder_reconfig(x4->enc, &x4->params);
            }
        }
    }
    do {
        //[libx264 API] 编码
        //
        // x264_picture_t --> x264_nal_t
        //
        if (x264_encoder_encode(x4->enc, &nal, &nnal, frame? &x4->pic: NULL, &pic_out) < 0)
            return -1;

        //把x264_nal_t赋值给AVPacket
        //
        // x264_nal_t --> AVPacket
        //
        ret = encode_nals(ctx, pkt, nal, nnal);
        if (ret < 0)
            return -1;
    } while (!ret && !frame && x264_encoder_delayed_frames(x4->enc));

    //赋值AVPacket相关的字段
    pkt->pts = pic_out.i_pts;
    pkt->dts = pic_out.i_dts;

    switch (pic_out.i_type) {
    case X264_TYPE_IDR:
    case X264_TYPE_I:
        ctx->coded_frame->pict_type = AV_PICTURE_TYPE_I;
        break;
    case X264_TYPE_P:
        ctx->coded_frame->pict_type = AV_PICTURE_TYPE_P;
        break;
    case X264_TYPE_B:
    case X264_TYPE_BREF:
        ctx->coded_frame->pict_type = AV_PICTURE_TYPE_B;
        break;
    }

    pkt->flags |= AV_PKT_FLAG_KEY*pic_out.b_keyframe;
    if (ret)
        ctx->coded_frame->quality = (pic_out.i_qpplus1 - 1) * FF_QP2LAMBDA;

    *got_packet = ret;
    return 0;
}
```

从源代码可以看出，X264_frame()调用x264_encoder_encode()完成了编码工作。x264_encoder_encode()的输入是x264_picture_t，输出是x264_nal_t；而X264_frame()的输入是AVFrame，输出是AVPacket。因此X264_frame()在调用编码函数前将AVFrame转换成了x264_picture_t，而在调用编码函数之后调用encode_nals()将x264_nal_t转换成了AVPacket。转换函数encode_nals()的定义如下所示。

[cpp]

```cpp
//把x264_nal_t赋值给AVPacket
//
// x264_nal_t --> AVPacket
//
static int encode_nals(AVCodecContext *ctx, AVPacket *pkt,
                       const x264_nal_t *nals, int nnal)
{
    X264Context *x4 = ctx->priv_data;
    uint8_t *p;
    int i, size = x4->sei_size, ret;

    if (!nnal)
        return 0;
    //NALU的大小
    //可能有多个NALU
    for (i = 0; i < nnal; i++)
        size += nals[i].i_payload;

    if ((ret = ff_alloc_packet2(ctx, pkt, size)) < 0)
        return ret;

    //p指向AVPacket的data
    p = pkt->data;

    /* Write the SEI as part of the first frame. */
    if (x4->sei_size > 0 && nnal > 0) {
        if (x4->sei_size > size) {
            av_log(ctx, AV_LOG_ERROR, "Error: nal buffer is too small\n");
            return -1;
        }
        memcpy(p, x4->sei, x4->sei_size);
        p += x4->sei_size;
        x4->sei_size = 0;
        av_freep(&x4->sei);
    }
    //拷贝x264_nal_t的数据至AVPacket的数据
    //可能有多个NALU
    for (i = 0; i < nnal; i++){
        memcpy(p, nals[i].p_payload, nals[i].i_payload);
        p += nals[i].i_payload;
    }

    return 1;
}
```

从源代码可以看出，encode_nals()的作用就是将多个x264_nal_t合并为一个AVPacket。

X264_close()

X264_close()用于关闭libx264解码器。该函数的定义如下所示。

[cpp]

```cpp
//libx264关闭解码器
static av_cold int X264_close(AVCodecContext *avctx)
{
    X264Context *x4 = avctx->priv_data;

    av_freep(&avctx->extradata);
    av_freep(&x4->sei);

    //[libx264 API] 关闭解码器
    if (x4->enc)
        x264_encoder_close(x4->enc);

    av_frame_free(&avctx->coded_frame);

    return 0;
}
```

可以看出X264_close()调用x264_encoder_close()关闭了libx264编码器。

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文章标签： libx264 FFmpeg H.264 视频编码 AVCodec

个人分类： x264 FFMPEG

所属专栏： FFmpeg