原 x264源代码简单分析：x264命令行工具（x264.exe）

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H.264源代码分析文章列表：

【编码 - x264】

【解码 - libavcodec H.264 解码器】

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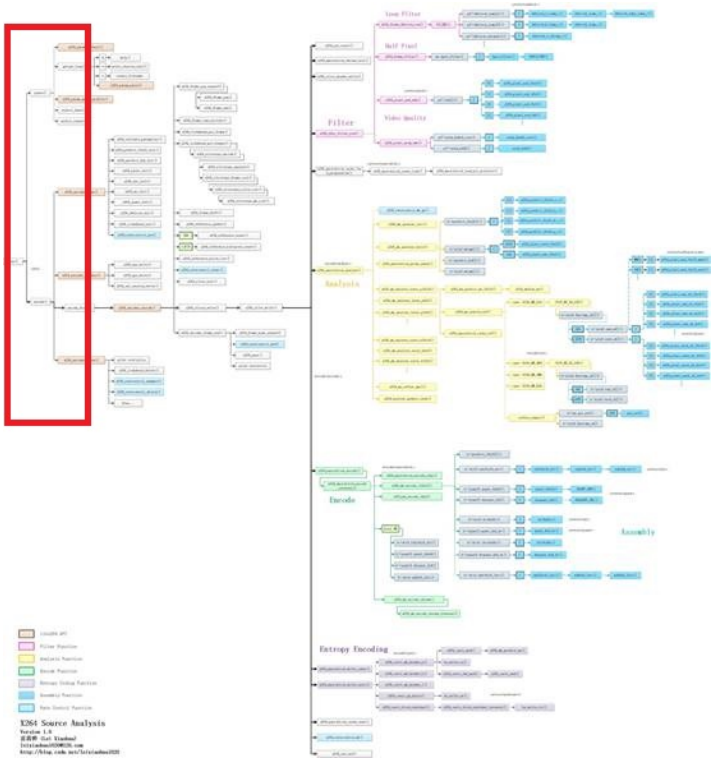
本文简单分析x264项目中的命令行工具（x264.exe）的源代码。该命令行工具可以调用libx264将YUV格式像素数据编码为H.264码流。

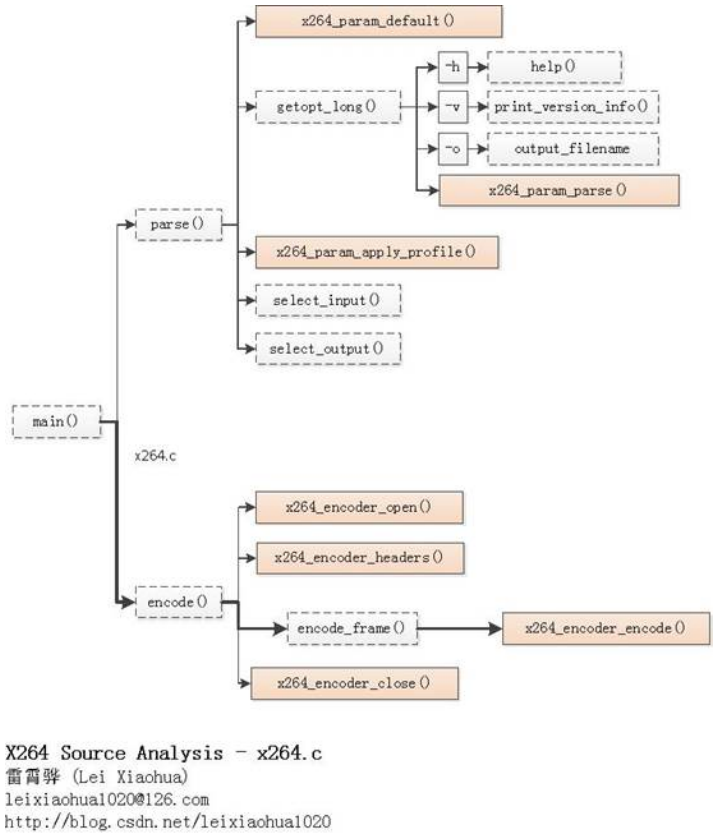
函数调用关系图

X264命令行工具的源代码在x264中的位置如下图所示。



单击查看更清晰的图片

X264命令行工具的源代码的调用关系如下图所示。



单击查看更清晰的图片

从图中可以看出，X264命令行工具调用了libx264的几个API完成了H.264编码工作。使用libx264的API进行编码可以参考《最简单的视频编码器：基于libx264（编码YUV为H.264）》，这个流程中最关键的API包括：

x264_param_default()：设置参数集结构体x264_param_t的缺省值。

x264_encoder_open()：打开编码器。

x264_encoder_headers()：输出SPS，PPS，SEI等信息。

x264_encoder_encode()：编码输出一帧图像。

x264_encoder_close()：关闭编码器。

在X264命令行工具中，main()首先调用parse()解析输入的命令行参数，然后调用encode()进行编码。parse()首先调用x264_param_default()为存储参数的结构体x264_param_t赋默认值；然后在一个大循环中调用getopt_long()逐个解析输入的参数，并作相应的处理；最后调用select_input()和s

elect_output()解析输入文件格式（例如yuv，y4m…）和输出文件格式（例如raw，flv，MP4…）。encode()首先调用x264_encoder_open()打开H.264编码器，然后调用x264_encoder_headers()输出H.264码流的头信息（例如SPS、PPS、SEI），接着进入一个循环并且调用encode_frame()逐帧编码视频，最后调用x264_encoder_close()关闭解码器。其中encode_frame()中又调用了x264_encoder_encode()完成了具体的编码工作。下文将会对上述流程展开分析。

main()

main()是x264控制台程序的入口函数，定义如下所示。

[cpp]

```cpp
//主函数
int main( int argc, char **argv )
{
    //参数集
    x264_param_t param;
    cli_opt_t opt = {0};
    int ret = 0;

    FAIL_IF_ERROR( x264_threading_init(), "unable to initialize threading\n" )

#ifdef _WIN32
    FAIL_IF_ERROR( !get_argv_utf8( &argc, &argv ), "unable to convert command line to UTF-8\n" )

    GetConsoleTitleW( org_console_title, CONSOLE_TITLE_SIZE );
    _setmode( _fileno( stdin ),  _O_BINARY );
    _setmode( _fileno( stdout ), _O_BINARY );
    _setmode( _fileno( stderr ), _O_BINARY );
#endif

    /* Parse command line */
    //解析命令行输入
    if( parse( argc, argv, ¶m, &opt ) < 0 )
        ret = -1;

#ifdef _WIN32
    /* Restore title; it can be changed by input modules */
    SetConsoleTitleW( org_console_title );
#endif

    /* Control-C handler */
    signal( SIGINT, sigint_handler );
    //编码
    if( !ret )
        ret = encode( ¶m, &opt );

    /* clean up handles */
    if( filter.free )
        filter.free( opt.hin );
    else if( opt.hin )
        cli_input.close_file( opt.hin );
    if( opt.hout )
        cli_output.close_file( opt.hout, 0, 0 );
    if( opt.tcfile_out )
        fclose( opt.tcfile_out );
    if( opt.qpfile )
        fclose( opt.qpfile );

#ifdef _WIN32
    SetConsoleTitleW( org_console_title );
    free( argv );
#endif

    return ret;
}
```

可以看出main()的定义很简单，它主要调用了两个函数：parse()和encode()。main()首先调用parse()解析输入的命令行参数，然后调用encode()进行编码。下面分别分析这两个函数。

parse()

parse()用于解析命令行输入的参数（存储于argv[]中）。它的定义如下所示。

[cpp]

```cpp
//解析命令行输入
static int parse( int argc, char **argv, x264_param_t *param, cli_opt_t *opt )
{
    char *input_filename = NULL;
```

```
    char *input_filename = NULL;
    const char *demuxer = demuxer_names[0];
    char *output_filename = NULL;
    const char *muxer = muxer_names[0];
    char *tcfile_name = NULL;
    x264_param_t defaults;
    char *profile = NULL;
    char *vid_filters = NULL;
    int b_thread_input = 0;
    int b_turbo = 1;
    int b_user_ref = 0;
    int b_user_fps = 0;
    int b_user_interlaced = 0;
    cli_input_opt_t input_opt;
    cli_output_opt_t output_opt;
    char *preset = NULL;
    char *tune = NULL;
    //初始化参数默认值
    x264_param_default( &defaults );
    cli_log_level = defaults.i_log_level;

    memset( &input_opt, 0, sizeof(cli_input_opt_t) );
    memset( &output_opt, 0, sizeof(cli_output_opt_t) );
    input_opt.bit_depth = 8;
    input_opt.input_range = input_opt.output_range = param->vui.b_fullrange = RANGE_AUTO;
    int output_csp = defaults.i_csp;
    opt->b_progress = 1;

    /* Presets are applied before all other options. */
    for( optind = 0;; )
    {
        int c = getopt_long( argc, argv, short_options, long_options, NULL );
        if( c == -1 )
            break;
        if( c == OPT_PRESET )
            preset = optarg;
        if( c == OPT_TUNE )
            tune = optarg;
        else if( c == '?' )
            return -1;
    }

    if( preset && !strcasecmp( preset, "placebo" ) )
        b_turbo = 0;
    //设置preset, tune
    if( x264_param_default_preset( param, preset, tune ) < 0 )
        return -1;

    /* Parse command line options */
    //解析命令行选项
    for( optind = 0;; )
    {
        int b_error = 0;
        int long_options_index = -1;

        int c = getopt_long( argc, argv, short_options, long_options, &long_options_index );

        if( c == -1 )
        {
            break;
        }
        //不同的选项做不同的处理
        switch( c )
        {
            case 'h':
                help( &defaults, 0 );//"-h"帮助菜单
                exit(0);
            case OPT_LONGHELP:
                help( &defaults, 1 );
                exit(0);
            case OPT_FULLHELP:
                help( &defaults, 2 );
                exit(0);
            case 'V':
                print_version_info();//打印版本信息
                exit(0);
            case OPT_FRAMES:
                param->i_frame_total = X264_MAX( atoi( optarg ), 0 );
                break;
            case OPT_SEEK:
                opt->i_seek = X264_MAX( atoi( optarg ), 0 );
                break;
            case 'o':
                output_filename = optarg;//输出文件路径
                break;
            case OPT_MUXER:
                FAIL_IF_ERROR( parse_enum_name( optarg, muxer_names, &muxer ), "Unknown muxer `%s'\n", optarg )
                break;
            case OPT_DEMUXER:
                FAIL_IF_ERROR( parse_enum_name( optarg, demuxer_names, &demuxer ), "Unknown demuxer `%s'\n", optarg )
                break;
            case OPT_INDEX:
```

```
                input_opt.index_file = optarg;
                break;
            case OPT_QPFILE:
                opt->qpfile = x264_fopen( optarg, "rb" );
                FAIL_IF_ERROR( !opt->qpfile, "can't open qpfile `%s'\n", optarg )
                if( !x264_is_regular_file( opt->qpfile ) )
                {
                    x264_cli_log( "x264", X264_LOG_ERROR, "qpfile incompatible with non-regular file `%s'\n", optarg );
                    fclose( opt->qpfile );
                    return -1;
                }
                break;
            case OPT_THREAD_INPUT:
                b_thread_input = 1;
                break;
            case OPT_QUIET:
                cli_log_level = param->i_log_level = X264_LOG_NONE;//设置log级别
                break;
            case 'v':
                cli_log_level = param->i_log_level = X264_LOG_DEBUG;//设置log级别
                break;
            case OPT_LOG_LEVEL:
                if( !parse_enum_value( optarg, log_level_names, &cli_log_level ) )
                    cli_log_level += X264_LOG_NONE;
                else
                    cli_log_level = atoi( optarg );
                param->i_log_level = cli_log_level;//设置log级别
                break;
            case OPT_NOPROGRESS:
                opt->b_progress = 0;
                break;
            case OPT_TUNE:
            case OPT_PRESET:
                break;
            case OPT_PROFILE:
                profile = optarg;
                break;
            case OPT_SLOWFIRSTPASS:
                b_turbo = 0;
                break;
            case 'r':
                b_user_ref = 1;
                goto generic_option;
            case OPT_FPS:
                b_user_fps = 1;
                param->b_vfr_input = 0;
                goto generic_option;
            case OPT_INTERLACED:
                b_user_interlaced = 1;
                goto generic_option;
            case OPT_TCFILE_IN:
                tcfile_name = optarg;
                break;
            case OPT_TCFILE_OUT:
                opt->tcfile_out = x264_fopen( optarg, "wb" );
                FAIL_IF_ERROR( !opt->tcfile_out, "can't open `%s'\n", optarg )
                break;
            case OPT_TIMEBASE:
                input_opt.timebase = optarg;
                break;
            case OPT_PULLDOWN:
                FAIL_IF_ERROR( parse_enum_value( optarg, pulldown_names, &opt->i_pulldown ), "Unknown pulldown `%s'\n", optarg )
                break;
            case OPT_VIDEO_FILTER:
                vid_filters = optarg;
                break;
            case OPT_INPUT_FMT:
                input_opt.format = optarg;//输入文件格式
                break;
            case OPT_INPUT_RES:
                input_opt.resolution = optarg;//输入分辨率
                break;
            case OPT_INPUT_CSP:
                input_opt.colorspace = optarg;//输入色域
                break;
            case OPT_INPUT_DEPTH:
                input_opt.bit_depth = atoi( optarg );//输入颜色位深
                break;
            case OPT_DTS_COMPRESSION:
                output_opt.use_dts_compress = 1;
                break;
            case OPT_OUTPUT_CSP:
                FAIL_IF_ERROR( parse_enum_value( optarg, output_csp_names, &output_csp ), "Unknown output csp `%s'\n", optarg )
                // correct the parsed value to the libx264 csp value
#if X264_CHROMA_FORMAT
                static const uint8_t output_csp_fix[] = { X264_CHROMA_FORMAT, X264_CSP_RGB };
#else
                static const uint8_t output_csp_fix[] = { X264_CSP_I420, X264_CSP_I422, X264_CSP_I444, X264_CSP_RGB };
#endif
                param->i_csp = output_csp = output_csp_fix[output_csp];
                break;
```

```
            case OPT_INPUT_RANGE:
                FAIL_IF_ERROR( parse_enum_value( optarg, range_names, &input_opt.input_range ), "Unknown input range `%s'\n", optarg )
                input_opt.input_range += RANGE_AUTO;
                break;
            case OPT_RANGE:
                FAIL_IF_ERROR( parse_enum_value( optarg, range_names, ¶m->vui.b_fullrange ), "Unknown range `%s'\n", optarg );
                input_opt.output_range = param->vui.b_fullrange += RANGE_AUTO;
                break;
            default:
generic_option:
            {
                if( long_options_index < 0 )
                {
                    for( int i = 0; long_options[i].name; i++ )
                        if( long_options[i].val == c )
                        {
                            long_options_index = i;
                            break;
                        }
                    if( long_options_index < 0 )
                    {
                        /* getopt_long already printed an error message */
                        return -1;
                    }
                }
                //解析以字符串方式输入的参数
                //即选项名称和选项值都是字符串
                b_error |= x264_param_parse( param, long_options[long_options_index].name, optarg );
            }
        }

        if( b_error )
        {
            const char *name = long_options_index > 0 ? long_options[long_options_index].name : argv[optind-2];
            x264_cli_log( "x264", X264_LOG_ERROR, "invalid argument: %s = %s\n", name, optarg );
            return -1;
        }
    }

    /* If first pass mode is used, apply faster settings. */
    if( b_turbo )
        x264_param_apply_fastfirstpass( param );

    /* Apply profile restrictions. */
    //设置profile
    if( x264_param_apply_profile( param, profile ) < 0 )
        return -1;

    /* Get the file name */
    FAIL_IF_ERROR( optind > argc - 1 || !output_filename, "No %s file. Run x264 --help for a list of options.\n",
                   optind > argc - 1 ? "input" : "output" )
    //根据文件名的后缀确定输出的文件格式（raw H264，flv，mp4...）
    if( select_output( muxer, output_filename, param ) )
        return -1;
    FAIL_IF_ERROR( cli_output.open_file( output_filename, &opt->hout, &output_opt ), "could not open output file `%s'\n", output_filename )
    //输入文件路径
    input_filename = argv[optind++];
    video_info_t info = {0};
    char demuxername[5];

    /* set info flags to be overwritten by demuxer as necessary. */
    //设置info结构体
    info.csp        = param->i_csp;
    info.fps_num    = param->i_fps_num;
    info.fps_den    = param->i_fps_den;
    info.fullrange  = input_opt.input_range == RANGE_PC;
    info.interlaced = param->b_interlaced;
    if( param->vui.i_sar_width > 0 && param->vui.i_sar_height > 0 )
    {
        info.sar_width  = param->vui.i_sar_width;
        info.sar_height = param->vui.i_sar_height;
    }
    info.tff        = param->b_tff;
    info.vfr        = param->b_vfr_input;

    input_opt.seek = opt->i_seek;
    input_opt.progress = opt->b_progress;
    input_opt.output_csp = output_csp;
    //设置输入文件的格式（yuv，y4m...）
    if( select_input( demuxer, demuxername, input_filename, &opt->hin, &info, &input_opt ) )
        return -1;

    FAIL_IF_ERROR( !opt->hin && cli_input.open_file( input_filename, &opt->hin, &info, &input_opt ),
                   "could not open input file `%s'\n", input_filename )

    x264_reduce_fraction( &info.sar_width, &info.sar_height );
    x264_reduce_fraction( &info.fps_num, &info.fps_den );
    x264_cli_log( demuxername, X264_LOG_INFO, "%dx%d%c %u:%u @ %u/%u fps (%cfr)\n", info.width,
                  info.height, info.interlaced ? 'i' : 'p', info.sar_width, info.sar_height,
```

```
                 info.fps_num, info.fps_den, info.vfr ? 'v' : 'c' );

    if( tcfile_name )
    {
        FAIL_IF_ERROR( b_user_fps, "--fps + --tcfile-in is incompatible.\n" )
        FAIL_IF_ERROR( timecode_input.open_file( tcfile_name, &opt->hin, &info, &input_opt ), "timecode input failed\n" )
        cli_input = timecode_input;
    }
    else FAIL_IF_ERROR( !info.vfr && input_opt.timebase, "--timebase is incompatible with cfr input\n" )

    /* init threaded input while the information about the input video is unaltered by filtering */
#if HAVE_THREAD
    if( info.thread_safe && (b_thread_input || param->i_threads > 1
        || (param->i_threads == X264_THREADS_AUTO && x264_cpu_num_processors() > 1)) )
    {
        if( thread_input.open_file( NULL, &opt->hin, &info, NULL ) )
        {
            fprintf( stderr, "x264 [error]: threaded input failed\n" );
            return -1;
        }
        cli_input = thread_input;
    }
#endif

    /* override detected values by those specified by the user */
    if( param->vui.i_sar_width > 0 && param->vui.i_sar_height > 0 )
    {
        info.sar_width  = param->vui.i_sar_width;
        info.sar_height = param->vui.i_sar_height;
    }
    if( b_user_fps )
    {
        info.fps_num = param->i_fps_num;
        info.fps_den = param->i_fps_den;
    }
    if( !info.vfr )
    {
        info.timebase_num = info.fps_den;
        info.timebase_den = info.fps_num;
    }
    if( !tcfile_name && input_opt.timebase )
    {
        uint64_t i_user_timebase_num;
        uint64_t i_user_timebase_den;
        int ret = sscanf( input_opt.timebase, "%"SCNu64"/%"SCNu64, &i_user_timebase_num, &i_user_timebase_den );
        FAIL_IF_ERROR( !ret, "invalid argument: timebase = %s\n", input_opt.timebase )
        else if( ret == 1 )
        {
            i_user_timebase_num = info.timebase_num;
            i_user_timebase_den = strtoul( input_opt.timebase, NULL, 10 );
        }
        FAIL_IF_ERROR( i_user_timebase_num > UINT32_MAX || i_user_timebase_den > UINT32_MAX,
                       "timebase you specified exceeds H.264 maximum\n" )
        opt->timebase_convert_multiplier = ((double)i_user_timebase_den / info.timebase_den)
                                         * ((double)info.timebase_num / i_user_timebase_num);
        info.timebase_num = i_user_timebase_num;
        info.timebase_den = i_user_timebase_den;
        info.vfr = 1;
    }
    if( b_user_interlaced )
    {
        info.interlaced = param->b_interlaced;
        info.tff = param->b_tff;
    }
    if( input_opt.input_range != RANGE_AUTO )
        info.fullrange = input_opt.input_range;

    //初始化滤镜filter
    //filter可以认为是一种“扩展”了的输入源
    if( init_vid_filters( vid_filters, &opt->hin, &info, param, output_csp ) )
        return -1;

    /* set param flags from the post-filtered video */
    param->b_vfr_input = info.vfr;
    param->i_fps_num = info.fps_num;
    param->i_fps_den = info.fps_den;
    param->i_timebase_num = info.timebase_num;
    param->i_timebase_den = info.timebase_den;
    param->vui.i_sar_width  = info.sar_width;
    param->vui.i_sar_height = info.sar_height;

    info.num_frames = X264_MAX( info.num_frames - opt->i_seek, 0 );
    if( (!info.num_frames || param->i_frame_total < info.num_frames)
        && param->i_frame_total > 0 )
        info.num_frames = param->i_frame_total;
    param->i_frame_total = info.num_frames;

    if( !b_user_interlaced && info.interlaced )
    {
#if HAVE_INTERLACED
        x264_cli_log( "x264", X264_LOG_WARNING, "input appears to be interlaced, enabling %cff interlaced mode.\n"
```

```
                        "                If you want otherwise, use --no-interlaced or --%cff\n",
                        info.tff ? 't' : 'b', info.tff ? 'b' : 't' );
        param->b_interlaced = 1;
        param->b_tff = !!info.tff;
#else
        x264_cli_log( "x264", X264_LOG_WARNING, "input appears to be interlaced, but not compiled with interlaced support\n" );
#endif
    }
    /* if the user never specified the output range and the input is now rgb, default it to pc */
    int csp = param->i_csp & X264_CSP_MASK;
    if( csp >= X264_CSP_BGR && csp <= X264_CSP_RGB )
    {
        if( input_opt.output_range == RANGE_AUTO )
            param->vui.b_fullrange = RANGE_PC;
        /* otherwise fail if they specified tv */
        FAIL_IF_ERROR( !param->vui.b_fullrange, "RGB must be PC range" )
    }

    /* Automatically reduce reference frame count to match the user's target level
     * if the user didn't explicitly set a reference frame count. */
    if( !b_user_ref )
    {
        int mbs = (((param->i_width)+15)>>4) * (((param->i_height)+15)>>4);
        for( int i = 0; x264_levels[i].level_idc != 0; i++ )
            if( param->i_level_idc == x264_levels[i].level_idc )
            {
                while( mbs * param->i_frame_reference > x264_levels[i].dpb && param->i_frame_reference > 1 )
                    param->i_frame_reference--;
                break;
            }
    }


    return 0;
}
```

下面简单梳理parse()的流程：

（1）调用x264_param_default()为存储参数的结构体x264_param_t赋默认值

（2）调用x264_param_default_preset()为x264_param_t赋值

（3）在一个大循环中调用getopt_long()逐个解析输入的参数，并作相应的处理。举几个例子：

a)“-h”：调用help()打开帮助菜单。

b)“-V”调用print_version_info()打印版本信息。

c)对于长选项，调用x264_param_parse()进行处理。

（4）调用select_input()解析输出文件格式（例如raw，flv，MP4…）

（5）调用select_output()解析输入文件格式（例如yuv，y4m…）

下文按照顺序记录parse()中涉及到的函数：

x264_param_default()
x264_param_default_preset()
help()
print_version_info()
x264_param_parse()
select_input()
select_output()

x264_param_default()

x264_param_default()是一个x264的API。该函数用于设置x264中x264_param_t结构体的默认值。函数的声明如下所示。

[cpp]

```cpp
/* x264_param_default:
 *      fill x264_param_t with default values and do CPU detection */
void    x264_param_default( x264_param_t * );
```

x264_param_default()的定义如下所示。

[cpp]

```cpp
/****************************************************************************
 * x264_param_default:
 ****************************************************************************/
//初始化参数默认值
void x264_param_default( x264_param_t *param )
{
    /* */
    memset( param, 0, sizeof( x264_param_t ) );

    /* CPU autodetect */
    param->cpu = x264_cpu_detect();
    param->i_threads = X264_THREADS_AUTO;
    param->i_lookahead_threads = X264_THREADS_AUTO;
```

```
    param->b_deterministic = 1;
    param->i_sync_lookahead = X264_SYNC_LOOKAHEAD_AUTO;

    /* Video properties */
    param->i_csp           = X264_CHROMA_FORMAT ? X264_CHROMA_FORMAT : X264_CSP_I420;
    param->i_width         = 0;
    param->i_height        = 0;
    param->vui.i_sar_width = 0;
    param->vui.i_sar_height= 0;
    param->vui.i_overscan  = 0;  /* undef */
    param->vui.i_vidformat = 5;  /* undef */
    param->vui.b_fullrange = -1; /* default depends on input */
    param->vui.i_colorprim = 2;  /* undef */
    param->vui.i_transfer  = 2;  /* undef */
    param->vui.i_colmatrix = -1; /* default depends on input */
    param->vui.i_chroma_loc= 0;  /* left center */
    param->i_fps_num       = 25;
    param->i_fps_den       = 1;
    param->i_level_idc     = -1;
    param->i_slice_max_size = 0;
    param->i_slice_max_mbs = 0;
    param->i_slice_count = 0;

    /* Encoder parameters */
    //编码参数--最常见
    param->i_frame_reference = 3;
    param->i_keyint_max = 250;
    param->i_keyint_min = X264_KEYINT_MIN_AUTO;
    param->i_bframe = 3;
    param->i_scenecut_threshold = 40;
    param->i_bframe_adaptive = X264_B_ADAPT_FAST;
    param->i_bframe_bias = 0;
    param->i_bframe_pyramid = X264_B_PYRAMID_NORMAL;
    param->b_interlaced = 0;
    param->b_constrained_intra = 0;

    param->b_deblocking_filter = 1;
    param->i_deblocking_filter_alphac0 = 0;
    param->i_deblocking_filter_beta = 0;

    param->b_cabac = 1;
    param->i_cabac_init_idc = 0;
    //码率控制模块 Rate Control
    param->rc.i_rc_method = X264_RC_CRF;
    param->rc.i_bitrate = 0;
    param->rc.f_rate_tolerance = 1.0;
    param->rc.i_vbv_max_bitrate = 0;
    param->rc.i_vbv_buffer_size = 0;
    param->rc.f_vbv_buffer_init = 0.9;
    param->rc.i_qp_constant = 23 + QP_BD_OFFSET;
    param->rc.f_rf_constant = 23;
    param->rc.i_qp_min = 0;
    param->rc.i_qp_max = QP_MAX;
    param->rc.i_qp_step = 4;
    param->rc.f_ip_factor = 1.4;
    param->rc.f_pb_factor = 1.3;
    param->rc.i_aq_mode = X264_AQ_VARIANCE;
    param->rc.f_aq_strength = 1.0;
    param->rc.i_lookahead = 40;

    param->rc.b_stat_write = 0;
    param->rc.psz_stat_out = "x264_2pass.log";
    param->rc.b_stat_read = 0;
    param->rc.psz_stat_in = "x264_2pass.log";
    param->rc.f_qcompress = 0.6;
    param->rc.f_qblur = 0.5;
    param->rc.f_complexity_blur = 20;
    param->rc.i_zones = 0;
    param->rc.b_mb_tree = 1;

    /* Log */
    //日志模块
    param->pf_log = x264_log_default;
    param->p_log_private = NULL;
    param->i_log_level = X264_LOG_INFO;

    /* */
    //分析模块 Analysis
    param->analyse.intra = X264_ANALYSE_I4x4 | X264_ANALYSE_I8x8;
    param->analyse.inter = X264_ANALYSE_I4x4 | X264_ANALYSE_I8x8
                         | X264_ANALYSE_PSUB16x16 | X264_ANALYSE_BSUB16x16;
    param->analyse.i_direct_mv_pred = X264_DIRECT_PRED_SPATIAL;
    param->analyse.i_me_method = X264_ME_HEX;
    param->analyse.f_psy_rd = 1.0;
    param->analyse.b_psy = 1;
    param->analyse.f_psy_trellis = 0;
    param->analyse.i_me_range = 16;
    param->analyse.i_subpel_refine = 7;
    param->analyse.b_mixed_references = 1;
    param->analyse.b_chroma_me = 1;
    param->analyse.i_mv_range_thread = -1;
```

```
    param->analyse.i_mv_range = -1; // set from level_idc
    param->analyse.i_chroma_qp_offset = 0;
    param->analyse.b_fast_pskip = 1;
    param->analyse.b_weighted_bipred = 1;
    param->analyse.i_weighted_pred = X264_WEIGHTP_SMART;
    param->analyse.b_dct_decimate = 1;
    param->analyse.b_transform_8x8 = 1;
    param->analyse.i_trellis = 1;
    param->analyse.i_luma_deadzone[0] = 21;
    param->analyse.i_luma_deadzone[1] = 11;
    param->analyse.b_psnr = 0;
    param->analyse.b_ssim = 0;

    param->i_cqm_preset = X264_CQM_FLAT;
    memset( param->cqm_4iy, 16, sizeof( param->cqm_4iy ) );
    memset( param->cqm_4py, 16, sizeof( param->cqm_4py ) );
    memset( param->cqm_4ic, 16, sizeof( param->cqm_4ic ) );
    memset( param->cqm_4pc, 16, sizeof( param->cqm_4pc ) );
    memset( param->cqm_8iy, 16, sizeof( param->cqm_8iy ) );
    memset( param->cqm_8py, 16, sizeof( param->cqm_8py ) );
    memset( param->cqm_8ic, 16, sizeof( param->cqm_8ic ) );
    memset( param->cqm_8pc, 16, sizeof( param->cqm_8pc ) );

    param->b_repeat_headers = 1;
    param->b_annexb = 1;
    param->b_aud = 0;
    param->b_vfr_input = 1;
    param->i_nal_hrd = X264_NAL_HRD_NONE;
    param->b_tff = 1;
    param->b_pic_struct = 0;
    param->b_fake_interlaced = 0;
    param->i_frame_packing = -1;
    param->b_opencl = 0;
    param->i_opencl_device = 0;
    param->opencl_device_id = NULL;
    param->psz_clbin_file = NULL;
}
```

从源代码可以看出，x264_param_default()对输入的存储参数的结构体x264_param_t的成员变量进行了赋值工作。

x264_param_default_preset()

x264_param_default_preset()是一个libx264的API，用于设置x264的preset和tune。该函数的声明如下所示。

[cpp]

```cpp
/*      Multiple tunings can be used if separated by a delimiter in ",./-+",
 *      however multiple psy tunings cannot be used.
 *      film, animation, grain, stillimage, psnr, and ssim are psy tunings.
 *
 *      returns 0 on success, negative on failure (e.g. invalid preset/tune name). */
int     x264_param_default_preset( x264_param_t *, const char *preset, const char *tune );
```

x264_param_default_preset()的定义如下所示。

[cpp]

```cpp
//设置preset，tune
int x264_param_default_preset( x264_param_t *param, const char *preset, const char *tune )
{
    x264_param_default( param );

    //设置preset
    if( preset && x264_param_apply_preset( param, preset ) < 0 )
        return -1;

    //设置tune
    if( tune && x264_param_apply_tune( param, tune ) < 0 )
        return -1;
    return 0;
}
```

从源代码可以看出，x264_param_default_preset()调用x264_param_apply_preset()设置preset，调用x264_param_apply_tune()设置tune。记录一下这两个函数。

x264_param_apply_preset()

x264_param_apply_preset()用于设置preset。该函数的定义如下所示。

[cpp]

```cpp
//设置preset
static int x264_param_apply_preset( x264_param_t *param, const char *preset )
{
    char *end;
    int i = strtol( preset, &end, 10 );
    if( *end == 0 && i >= 0 && i < sizeof(x264_preset_names)/sizeof(*x264_preset_names)-1 )
        preset = x264_preset_names[i];

```

```
    //几种不同的preset设置不同的参数
    if( !strcasecmp( preset, "ultrafast" ) )
    {
        param->i_frame_reference = 1;
        param->i_scenecut_threshold = 0;
        param->b_deblocking_filter = 0;//不使用去块滤波
        param->b_cabac = 0;//不使用CABAC
        param->i_bframe = 0;//不使用B帧
        param->analyse.intra = 0;
        param->analyse.inter = 0;
        param->analyse.b_transform_8x8 = 0;//不使用8x8DCT
        param->analyse.i_me_method = X264_ME_DIA;//运动搜索方法使用“Diamond”
        param->analyse.i_subpel_refine = 0;
        param->rc.i_aq_mode = 0;
        param->analyse.b_mixed_references = 0;
        param->analyse.i_trellis = 0;
        param->i_bframe_adaptive = X264_B_ADAPT_NONE;
        param->rc.b_mb_tree = 0;
        param->analyse.i_weighted_pred = X264_WEIGHTP_NONE;//不使用加权
        param->analyse.b_weighted_bipred = 0;
        param->rc.i_lookahead = 0;
    }
    else if( !strcasecmp( preset, "superfast" ) )
    {
        param->analyse.inter = X264_ANALYSE_I8x8|X264_ANALYSE_I4x4;
        param->analyse.i_me_method = X264_ME_DIA;//钻石模板
        param->analyse.i_subpel_refine = 1;//亚像素运动估计质量为1
        param->i_frame_reference = 1;
        param->analyse.b_mixed_references = 0;
        param->analyse.i_trellis = 0;
        param->rc.b_mb_tree = 0;
        param->analyse.i_weighted_pred = X264_WEIGHTP_SIMPLE;
        param->rc.i_lookahead = 0;
    }
    else if( !strcasecmp( preset, "veryfast" ) )
    {
        param->analyse.i_me_method = X264_ME_HEX;//六边形模板
        param->analyse.i_subpel_refine = 2;
        param->i_frame_reference = 1;
        param->analyse.b_mixed_references = 0;
        param->analyse.i_trellis = 0;
        param->analyse.i_weighted_pred = X264_WEIGHTP_SIMPLE;
        param->rc.i_lookahead = 10;
    }
    else if( !strcasecmp( preset, "faster" ) )
    {
        param->analyse.b_mixed_references = 0;
        param->i_frame_reference = 2;
        param->analyse.i_subpel_refine = 4;
        param->analyse.i_weighted_pred = X264_WEIGHTP_SIMPLE;
        param->rc.i_lookahead = 20;
    }
    else if( !strcasecmp( preset, "fast" ) )
    {
        param->i_frame_reference = 2;
        param->analyse.i_subpel_refine = 6;
        param->analyse.i_weighted_pred = X264_WEIGHTP_SIMPLE;
        param->rc.i_lookahead = 30;
    }
    else if( !strcasecmp( preset, "medium" ) )
    {
        /* Default is medium */
    }
    else if( !strcasecmp( preset, "slow" ) )
    {
        param->analyse.i_me_method = X264_ME_UMH;//UMH相对复杂
        param->analyse.i_subpel_refine = 8;//亚像素运动估计质量为8
        param->i_frame_reference = 5;
        param->i_bframe_adaptive = X264_B_ADAPT_TRELLIS;
        param->analyse.i_direct_mv_pred = X264_DIRECT_PRED_AUTO;
        param->rc.i_lookahead = 50;
    }
    else if( !strcasecmp( preset, "slower" ) )
    {
        param->analyse.i_me_method = X264_ME_UMH;
        param->analyse.i_subpel_refine = 9;
        param->i_frame_reference = 8;
        param->i_bframe_adaptive = X264_B_ADAPT_TRELLIS;
        param->analyse.i_direct_mv_pred = X264_DIRECT_PRED_AUTO;
        param->analyse.inter |= X264_ANALYSE_PSUB8x8;
        param->analyse.i_trellis = 2;
        param->rc.i_lookahead = 60;
    }
    else if( !strcasecmp( preset, "veryslow" ) )
    {
        param->analyse.i_me_method = X264_ME_UMH;
        param->analyse.i_subpel_refine = 10;
        param->analyse.i_me_range = 24;
        param->i_frame_reference = 16;
        param->i_bframe_adaptive = X264_B_ADAPT_TRELLIS;
        param->analyse.i_direct_mv_pred = X264_DIRECT_PRED_AUTO;
```

```
        param->analyse.inter |= X264_ANALYSE_PSUB8x8;
        param->analyse.i_trellis = 2;
        param->i_bframe = 8;
        param->rc.i_lookahead = 60;
    }
    else if( !strcasecmp( preset, "placebo" ) )
    {
        param->analyse.i_me_method = X264_ME_TESA;//TESA很慢
        param->analyse.i_subpel_refine = 11;
        param->analyse.i_me_range = 24;
        param->i_frame_reference = 16;
        param->i_bframe_adaptive = X264_B_ADAPT_TRELLIS;
        param->analyse.i_direct_mv_pred = X264_DIRECT_PRED_AUTO;
        param->analyse.inter |= X264_ANALYSE_PSUB8x8;
        param->analyse.b_fast_pskip = 0;
        param->analyse.i_trellis = 2;
        param->i_bframe = 16;
        param->rc.i_lookahead = 60;
    }
    else
    {
        x264_log( NULL, X264_LOG_ERROR, "invalid preset '%s'\n", preset );
        return -1;
    }
    return 0;
}
```

可以看出x264_param_apply_preset()通过strcasecmp()比较字符串的方法得到输入的preset类型；然后根据preset类型，设定 x264_param_t中相应的参数。

x264_param_apply_tune()

x264_param_apply_tune()用于设置tune。该函数的定义如下所示。

[cpp]

```cpp
//设置tune
static int x264_param_apply_tune( x264_param_t *param, const char *tune )
{
    char *tmp = x264_malloc( strlen( tune ) + 1 );
    if( !tmp )
        return -1;
    tmp = strcpy( tmp, tune );
    //分解一个字符串为一个字符串数组。第2个参数为分隔符
    char *s = strtok( tmp, ",./-+" );
    int psy_tuning_used = 0;

    //设置
    //这里是循环的，可以设置多次
    while( s )
    {
        if( !strncasecmp( s, "film", 4 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->i_deblocking_filter_alphac0 = -1;
            param->i_deblocking_filter_beta = -1;
            param->analyse.f_psy_trellis = 0.15;
        }
        else if( !strncasecmp( s, "animation", 9 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->i_frame_reference = param->i_frame_reference > 1 ? param->i_frame_reference*2 : 1;
            param->i_deblocking_filter_alphac0 = 1;
            param->i_deblocking_filter_beta = 1;
            param->analyse.f_psy_rd = 0.4;
            param->rc.f_aq_strength = 0.6;
            param->i_bframe += 2;
        }
        else if( !strncasecmp( s, "grain", 5 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->i_deblocking_filter_alphac0 = -2;
            param->i_deblocking_filter_beta = -2;
            param->analyse.f_psy_trellis = 0.25;
            param->analyse.b_dct_decimate = 0;
            param->rc.f_pb_factor = 1.1;
            param->rc.f_ip_factor = 1.1;
            param->rc.f_aq_strength = 0.5;
            param->analyse.i_luma_deadzone[0] = 6;
            param->analyse.i_luma_deadzone[1] = 6;
            param->rc.f_qcompress = 0.8;
        }
        else if( !strncasecmp( s, "stillimage", 10 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->i_deblocking_filter_alphac0 = -3;
            param->i_deblocking_filter_beta = -3;
            param->analyse.f_psy_rd = 2.0;
            param->analyse.f_psy_trellis = 0.7;
            param->rc.f_aq_strength = 1.2;
        }
```

```cpp
        else if( !strncasecmp( s, "psnr", 4 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->rc.i_aq_mode = X264_AQ_NONE;
            param->analyse.b_psy = 0;
        }
        else if( !strncasecmp( s, "ssim", 4 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->rc.i_aq_mode = X264_AQ_AUTOVARIANCE;
            param->analyse.b_psy = 0;
        }
        else if( !strncasecmp( s, "fastdecode", 10 ) )
        {
            param->b_deblocking_filter = 0;
            param->b_cabac = 0;
            param->analyse.b_weighted_bipred = 0;
            param->analyse.i_weighted_pred = X264_WEIGHTP_NONE;
        }
        else if( !strncasecmp( s, "zerolatency", 11 ) )
        {
            //zerolatency速度快
            param->rc.i_lookahead = 0;
            param->i_sync_lookahead = 0;
            param->i_bframe = 0;//不使用B帧
            param->b_sliced_threads = 1;
            param->b_vfr_input = 0;
            param->rc.b_mb_tree = 0;
        }
        else if( !strncasecmp( s, "touhou", 6 ) )
        {
            if( psy_tuning_used++ ) goto psy_failure;
            param->i_frame_reference = param->i_frame_reference > 1 ? param->i_frame_reference*2 : 1;
            param->i_deblocking_filter_alphac0 = -1;
            param->i_deblocking_filter_beta = -1;
            param->analyse.f_psy_trellis = 0.2;
            param->rc.f_aq_strength = 1.3;
            if( param->analyse.inter & X264_ANALYSE_PSUB16x16 )
                param->analyse.inter |= X264_ANALYSE_PSUB8x8;
        }
        else
        {
            x264_log( NULL, X264_LOG_ERROR, "invalid tune '%s'\n", s );
            x264_free( tmp );
            return -1;
        }
        if( 0 )
        {
    psy_failure:
            x264_log( NULL, X264_LOG_WARNING, "only 1 psy tuning can be used: ignoring tune %s\n", s );
        }
        s = strtok( NULL, ",./-+" );
    }
    x264_free( tmp );
    return 0;
}
```

可以看出x264_param_apply_tune()首先通过strtok()得到存储tune[]数组；然后通过strncasecmp()比较字符串的方法判断当前的tune类型；最后根据tune类型，设定 x264_param_t中相应的参数。

help()

help()用于打印帮助菜单。在x264命令行程序中添加"-h"参数后会调用该函数。该函数的定义如下所示。

[cpp]

```cpp
//帮助菜单
//longhelp标识是否展开更长的帮助菜单
static void help( x264_param_t *defaults, int longhelp )
{
    char buf[50];
    //H0(),H1(),H2()都是printf()
    //H1(),H2()只有"长帮助菜单"的情况下才会调用printf()
#define H0 printf
#define H1 if(longhelp>=1) printf
#define H2 if(longhelp==2) printf
    H0( "x264 core:%d%s\n"
        "Syntax: x264 [options] -o outfile infile\n"
        "\n"
        "Infile can be raw (in which case resolution is required),\n"
        "  or YUV4MPEG (*.y4m),\n"
        "  or Avisynth if compiled with support (%s).\n"
        "  or libav* formats if compiled with lavf support (%s) or ffms support (%s).\n"
        "Outfile type is selected by filename:\n"
        " .264 -> Raw bytestream\n"
        " .mkv -> Matroska\n"
        " .flv -> Flash Video\n"
        " .mp4 -> MP4 if compiled with GPAC or L-SMASH support (%s)\n"
        "Output bit depth: %d (configured at compile time)\n"
```

```
        "output bit depth: %d (configured at compile time)\n"
        "\n"
        "Options:\n"
        "\n"
        "  -h, --help                  List basic options\n"
        "      --longhelp              List more options\n"
        "      --fullhelp              List all options\n"
        "\n",
        X264_BUILD, X264_VERSION,
#if HAVE_AVS
        "yes",
#else
        "no",
#endif
#if HAVE_LAVF
        "yes",
#else
        "no",
#endif
#if HAVE_FFMS
        "yes",
#else
        "no",
#endif
#if HAVE_GPAC
        "gpac",
#elif HAVE_LSMASH
        "lsmash",
#else
        "no",
#endif
        x264_bit_depth
       );
    H0( "Example usage:\n" );
    H0( "\n" );
    H0( "      Constant quality mode:\n" );
    H0( "            x264 --crf 24 -o <output> <input>\n" );
    H0( "\n" );
    H0( "      Two-pass with a bitrate of 1000kbps:\n" );
    H0( "            x264 --pass 1 --bitrate 1000 -o <output> <input>\n" );
    H0( "            x264 --pass 2 --bitrate 1000 -o <output> <input>\n" );
    H0( "\n" );
    H0( "      Lossless:\n" );
    H0( "            x264 --qp 0 -o <output> <input>\n" );
    H0( "\n" );
    H0( "      Maximum PSNR at the cost of speed and visual quality:\n" );
    H0( "            x264 --preset placebo --tune psnr -o <output> <input>\n" );
    H0( "\n" );
    H0( "      Constant bitrate at 1000kbps with a 2 second-buffer:\n");
    H0( "            x264 --vbv-bufsize 2000 --bitrate 1000 -o <output> <input>\n" );
    H0( "\n" );
    H0( "Presets:\n" );
    H0( "\n" );
    H0( "      --profile <string>      Force the limits of an H.264 profile\n"
        "                                  Overrides all settings.\n" );
    H2(
#if X264_CHROMA_FORMAT <= X264_CSP_I420
#if BIT_DEPTH==8
        "                                  - baseline:\n"
        "                                    --no-8x8dct --bframes 0 --no-cabac\n"
        "                                    --cqm flat --weightp 0\n"
        "                                    No interlaced.\n"
        "                                    No lossless.\n"
        "                                  - main:\n"
        "                                    --no-8x8dct --cqm flat\n"
        "                                    No lossless.\n"
        "                                  - high:\n"
        "                                    No lossless.\n"
#endif
        "                                  - high10:\n"
        "                                    No lossless.\n"
        "                                    Support for bit depth 8-10.\n"
#endif
#if X264_CHROMA_FORMAT <= X264_CSP_I422
        "                                  - high422:\n"
        "                                    No lossless.\n"
        "                                    Support for bit depth 8-10.\n"
        "                                    Support for 4:2:0/4:2:2 chroma subsampling.\n"
#endif
        "                                  - high444:\n"
        "                                    Support for bit depth 8-10.\n"
        "                                    Support for 4:2:0/4:2:2/4:4:4 chroma subsampling.\n" );
        else H0(
        "                                  - "
#if X264_CHROMA_FORMAT <= X264_CSP_I420
#if BIT_DEPTH==8
        "baseline,main,high,"
#endif
        "high10,"
#endif
#if X264_CHROMA_FORMAT <= X264_CSP_I422
        "high422,"
```

```
#endif
        "high444\n"
                );
    H0( "      --preset <string>       Use a preset to select encoding settings [medium]\n"
        "                                  Overridden by user settings.\n" );
    H2( "                                  - ultrafast:\n"
        "                                    --no-8x8dct --aq-mode 0 --b-adapt 0\n"
        "                                    --bframes 0 --no-cabac --no-deblock\n"
        "                                    --no-mbtree --me dia --no-mixed-refs\n"
        "                                    --partitions none --rc-lookahead 0 --ref 1\n"
        "                                    --scenecut 0 --subme 0 --trellis 0\n"
        "                                    --no-weightb --weightp 0\n"
        "                                  - superfast:\n"
        "                                    --no-mbtree --me dia --no-mixed-refs\n"
        "                                    --partitions i8x8,i4x4 --rc-lookahead 0\n"
        "                                    --ref 1 --subme 1 --trellis 0 --weightp 1\n"
        "                                  - veryfast:\n"
        "                                    --no-mixed-refs --rc-lookahead 10\n"
        "                                    --ref 1 --subme 2 --trellis 0 --weightp 1\n"
        "                                  - faster:\n"
        "                                    --no-mixed-refs --rc-lookahead 20\n"
        "                                    --ref 2 --subme 4 --weightp 1\n"
        "                                  - fast:\n"
        "                                    --rc-lookahead 30 --ref 2 --subme 6\n"
        "                                    --weightp 1\n"
        "                                  - medium:\n"
        "                                    Default settings apply.\n"
        "                                  - slow:\n"
        "                                    --b-adapt 2 --direct auto --me umh\n"
        "                                    --rc-lookahead 50 --ref 5 --subme 8\n"
        "                                  - slower:\n"
        "                                    --b-adapt 2 --direct auto --me umh\n"
        "                                    --partitions all --rc-lookahead 60\n"
        "                                    --ref 8 --subme 9 --trellis 2\n"
        "                                  - veryslow:\n"
        "                                    --b-adapt 2 --bframes 8 --direct auto\n"
        "                                    --me umh --merange 24 --partitions all\n"
        "                                    --ref 16 --subme 10 --trellis 2\n"
        "                                    --rc-lookahead 60\n"
        "                                  - placebo:\n"
        "                                    --bframes 16 --b-adapt 2 --direct auto\n"
        "                                    --slow-firstpass --no-fast-pskip\n"
        "                                    --me tesa --merange 24 --partitions all\n"
        "                                    --rc-lookahead 60 --ref 16 --subme 11\n"
        "                                    --trellis 2\n" );
    else H0( "                                 - ultrafast,superfast,veryfast,faster,fast\n"
             "                                 - medium,slow,slower,veryslow,placebo\n" );
    H0( "      --tune <string>         Tune the settings for a particular type of source\n"
        "                              or situation\n"
        "                                  Overridden by user settings.\n"
        "                                  Multiple tunings are separated by commas.\n"
        "                                  Only one psy tuning can be used at a time.\n" );
    H2( "                                  - film (psy tuning):\n"
        "                                    --deblock -1:-1 --psy-rd <unset>:0.15\n"
        "                                  - animation (psy tuning):\n"
        "                                    --bframes {+2} --deblock 1:1\n"
        "                                    --psy-rd 0.4:<unset> --aq-strength 0.6\n"
        "                                    --ref {Double if >1 else 1}\n"
        "                                  - grain (psy tuning):\n"
        "                                    --aq-strength 0.5 --no-dct-decimate\n"
        "                                    --deadzone-inter 6 --deadzone-intra 6\n"
        "                                    --deblock -2:-2 --ipratio 1.1 \n"
        "                                    --pbratio 1.1 --psy-rd <unset>:0.25\n"
        "                                    --qcomp 0.8\n"
        "                                  - stillimage (psy tuning):\n"
        "                                    --aq-strength 1.2 --deblock -3:-3\n"
        "                                    --psy-rd 2.0:0.7\n"
        "                                  - psnr (psy tuning):\n"
        "                                    --aq-mode 0 --no-psy\n"
        "                                  - ssim (psy tuning):\n"
        "                                    --aq-mode 2 --no-psy\n"
        "                                  - fastdecode:\n"
        "                                    --no-cabac --no-deblock --no-weightb\n"
        "                                    --weightp 0\n"
        "                                  - zerolatency:\n"
        "                                    --bframes 0 --force-cfr --no-mbtree\n"
        "                                    --sync-lookahead 0 --sliced-threads\n"
        "                                    --rc-lookahead 0\n" );
    else H0( "                                 - psy tunings: film,animation,grain,\n"
             "                                                stillimage,psnr,ssim\n"
             "                                 - other tunings: fastdecode,zerolatency\n" );
    H2( "      --slow-firstpass        Don't force these faster settings with --pass 1:\n"
        "                              --no-8x8dct --me dia --partitions none\n"
        "                              --ref 1 --subme {2 if >2 else unchanged}\n"
        "                              --trellis 0 --fast-pskip\n" );
    else H1( "      --slow-firstpass        Don't force faster settings with --pass 1\n" );
    H0( "\n" );
    H0( "Frame-type options:\n" );
    H0( "\n" );
    H0( "  -I, --keyint <integer or \"infinite\"> Maximum GOP size [%d]\n", defaults->i_keyint_max );
    H2( "  -i, --min-keyint <integer>  Minimum GOP size [auto]\n" );
```

```
    H2( "      --no-scenecut           Disable adaptive I-frame decision\n" );
    H2( "      --scenecut <integer>    How aggressively to insert extra I-frames [%d]\n", defaults->i_scenecut_threshold );
    H2( "      --intra-refresh         Use Periodic Intra Refresh instead of IDR frames\n" );
    H1( "  -b, --bframes <integer>     Number of B-frames between I and P [%d]\n", defaults->i_bframe );
    H1( "      --b-adapt <integer>     Adaptive B-frame decision method [%d]\n"
        "                                  Higher values may lower threading efficiency.\n"
        "                                  - 0: Disabled\n"
        "                                  - 1: Fast\n"
        "                                  - 2: Optimal (slow with high --bframes)\n", defaults->i_bframe_adaptive );
    H2( "      --b-bias <integer>      Influences how often B-frames are used [%d]\n", defaults->i_bframe_bias );
    H1( "      --b-pyramid <string>    Keep some B-frames as references [%s]\n"
        "                                  - none: Disabled\n"
        "                                  - strict: Strictly hierarchical pyramid\n"
        "                                  - normal: Non-strict (not Blu-ray compatible)\n",
        strtable_lookup( x264_b_pyramid_names, defaults->i_bframe_pyramid ) );
    H1( "      --open-gop              Use recovery points to close GOPs\n"
        "                              Only available with b-frames\n" );
    H1( "      --no-cabac              Disable CABAC\n" );
    H1( "  -r, --ref <integer>         Number of reference frames [%d]\n", defaults->i_frame_reference );
    H1( "      --no-deblock            Disable loop filter\n" );
    H1( "  -f, --deblock <alpha:beta>  Loop filter parameters [%d:%d]\n",
                                       defaults->i_deblocking_filter_alphac0, defaults->i_deblocking_filter_beta );
    H2( "      --slices <integer>      Number of slices per frame; forces rectangular\n"
        "                              slices and is overridden by other slicing options\n" );
    else H1( "      --slices <integer>      Number of slices per frame\n" );
    H2( "      --slices-max <integer>  Absolute maximum slices per frame; overrides\n"
        "                              slice-max-size/slice-max-mbs when necessary\n" );
    H2( "      --slice-max-size <integer> Limit the size of each slice in bytes\n");
    H2( "      --slice-max-mbs <integer> Limit the size of each slice in macroblocks (max)\n");
    H2( "      --slice-min-mbs <integer> Limit the size of each slice in macroblocks (min)\n");
    H0( "      --tff                   Enable interlaced mode (top field first)\n" );
    H0( "      --bff                   Enable interlaced mode (bottom field first)\n" );
    H2( "      --constrained-intra     Enable constrained intra prediction.\n" );
    H0( "      --pulldown <string>     Use soft pulldown to change frame rate\n"
        "                                  - none, 22, 32, 64, double, triple, euro (requires cfr input)\n" );
    H2( "      --fake-interlaced       Flag stream as interlaced but encode progressive.\n"
        "                              Makes it possible to encode 25p and 30p Blu-Ray\n"
        "                              streams. Ignored in interlaced mode.\n" );
    H2( "      --frame-packing <integer> For stereoscopic videos define frame arrangement\n"
        "                                  - 0: checkerboard - pixels are alternatively from L and R\n"
        "                                  - 1: column alternation - L and R are interlaced by column\n"
        "                                  - 2: row alternation - L and R are interlaced by row\n"
        "                                  - 3: side by side - L is on the left, R on the right\n"
        "                                  - 4: top bottom - L is on top, R on bottom\n"
        "                                  - 5: frame alternation - one view per frame\n" );
    H0( "\n" );
    H0( "Ratecontrol:\n" );
    H0( "\n" );
    H1( "  -q, --qp <integer>          Force constant QP (0-%d, 0=lossless)\n", QP_MAX );
    H0( "  -B, --bitrate <integer>     Set bitrate (kbit/s)\n" );
    H0( "      --crf <float>           Quality-based VBR (%d-51) [%.1f]\n", 51 - QP_MAX_SPEC, defaults->rc.f_rf_constant );
    H1( "      --rc-lookahead <integer> Number of frames for frametype lookahead [%d]\n", defaults->rc.i_lookahead );
    H0( "      --vbv-maxrate <integer> Max local bitrate (kbit/s) [%d]\n", defaults->rc.i_vbv_max_bitrate );
    H0( "      --vbv-bufsize <integer> Set size of the VBV buffer (kbit) [%d]\n", defaults->rc.i_vbv_buffer_size );
    H2( "      --vbv-init <float>      Initial VBV buffer occupancy [%.1f]\n", defaults->rc.f_vbv_buffer_init );
    H2( "      --crf-max <float>       With CRF+VBV, limit RF to this value\n"
        "                                  May cause VBV underflows!\n" );
    H2( "      --qpmin <integer>       Set min QP [%d]\n", defaults->rc.i_qp_min );
    H2( "      --qpmax <integer>       Set max QP [%d]\n", defaults->rc.i_qp_max );
    H2( "      --qpstep <integer>      Set max QP step [%d]\n", defaults->rc.i_qp_step );
    H2( "      --ratetol <float>       Tolerance of ABR ratecontrol and VBV [%.1f]\n", defaults->rc.f_rate_tolerance );
    H2( "      --ipratio <float>       QP factor between I and P [%.2f]\n", defaults->rc.f_ip_factor );
    H2( "      --pbratio <float>       QP factor between P and B [%.2f]\n", defaults->rc.f_pb_factor );
    H2( "      --chroma-qp-offset <integer>  QP difference between chroma and luma [%d]\n", defaults->analyse.i_chroma_qp_offset );
    H2( "      --aq-mode <integer>     AQ method [%d]\n"
        "                                  - 0: Disabled\n"
        "                                  - 1: Variance AQ (complexity mask)\n"
        "                                  - 2: Auto-variance AQ (experimental)\n", defaults->rc.i_aq_mode );
    H1( "      --aq-strength <float>   Reduces blocking and blurring in flat and\n"
        "                              textured areas. [%.1f]\n", defaults->rc.f_aq_strength );
    H1( "\n" );
    H0( "  -p, --pass <integer>        Enable multipass ratecontrol\n"
        "                                  - 1: First pass, creates stats file\n"
        "                                  - 2: Last pass, does not overwrite stats file\n" );
    H2( "                                  - 3: Nth pass, overwrites stats file\n" );
    H1( "      --stats <string>        Filename for 2 pass stats [\"%s\"]\n", defaults->rc.psz_stat_out );
    H2( "      --no-mbtree             Disable mb-tree ratecontrol.\n");
    H2( "      --qcomp <float>         QP curve compression [%.2f]\n", defaults->rc.f_qcompress );
    H2( "      --cplxblur <float>      Reduce fluctuations in QP (before curve compression) [%.1f]\n", defaults->rc.f_complexity_blur );
    H2( "      --qblur <float>         Reduce fluctuations in QP (after curve compression) [%.1f]\n", defaults->rc.f_qblur );
    H2( "      --zones <zone0>/<zone1>/...  Tweak the bitrate of regions of the video\n" );
    H2( "                              Each zone is of the form\n"
        "                                  <start frame>,<end frame>,<option>\n"
        "                                  where <option> is either\n"
        "                                      q=<integer> (force QP)\n"
        "                                  or  b=<float> (bitrate multiplier)\n" );
    H2( "      --qpfile <string>       Force frametypes and QPs for some or all frames\n"
        "                              Format of each line: framenumber frametype QP\n"
        "                              QP is optional (none lets x264 choose). Frametypes: I,i,K,P,B,b.\n"
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```
        "                                   K=<I or i> depending on open-gop setting\n"
        "                               QPs are restricted by qpmin/qpmax.\n" );
    H1( "\n" );
    H1( "Analysis:\n" );
    H1( "\n" );
    H1( "  -A, --partitions <string>   Partitions to consider [\"p8x8,b8x8,i8x8,i4x4\"]\n"
        "                                   - p8x8, p4x4, b8x8, i8x8, i4x4\n"
        "                                   - none, all\n"
        "                                   (p4x4 requires p8x8. i8x8 requires --8x8dct.)\n" );
    H1( "      --direct <string>       Direct MV prediction mode [\"%s\"]\n"
        "                                   - none, spatial, temporal, auto\n",
                                        strtable_lookup( x264_direct_pred_names, defaults->analyse.i_direct_mv_pred ) );
    H2( "      --no-weightb            Disable weighted prediction for B-frames\n" );
    H1( "      --weightp <integer>     Weighted prediction for P-frames [%d]\n"
        "                                   - 0: Disabled\n"
        "                                   - 1: Weighted refs\n"
        "                                   - 2: Weighted refs + Duplicates\n", defaults->analyse.i_weighted_pred );
    H1( "      --me <string>           Integer pixel motion estimation method [\"%s\"]\n",
                                        strtable_lookup( x264_motion_est_names, defaults->analyse.i_me_method ) );
    H2( "                                   - dia: diamond search, radius 1 (fast)\n"
        "                                   - hex: hexagonal search, radius 2\n"
        "                                   - umh: uneven multi-hexagon search\n"
        "                                   - esa: exhaustive search\n"
        "                                   - tesa: hadamard exhaustive search (slow)\n" );
    else H1( "                                  - dia, hex, umh\n" );
    H2( "      --merange <integer>     Maximum motion vector search range [%d]\n", defaults->analyse.i_me_range );
    H2( "      --mvrange <integer>     Maximum motion vector length [-1 (auto)]\n" );
    H2( "      --mvrange-thread <int>  Minimum buffer between threads [-1 (auto)]\n" );
    H1( "  -m, --subme <integer>       Subpixel motion estimation and mode decision [%d]\n", defaults->analyse.i_subpel_refine );
    H2( "                                   - 0: fullpel only (not recommended)\n"
        "                                   - 1: SAD mode decision, one qpel iteration\n"
        "                                   - 2: SATD mode decision\n"
        "                                   - 3-5: Progressively more qpel\n"
        "                                   - 6: RD mode decision for I/P-frames\n"
        "                                   - 7: RD mode decision for all frames\n"
        "                                   - 8: RD refinement for I/P-frames\n"
        "                                   - 9: RD refinement for all frames\n"
        "                                   - 10: QP-RD - requires trellis=2, aq-mode>0\n"
        "                                   - 11: Full RD: disable all early terminations\n" );
    else H1( "                                  decision quality: 1=fast, 11=best\n" );
    H1( "      --psy-rd <float:float>  Strength of psychovisual optimization [\"%.1f:%.1f\"]\n"
        "                                   #1: RD (requires subme>=6)\n"
        "                                   #2: Trellis (requires trellis, experimental)\n",
                                        defaults->analyse.f_psy_rd, defaults->analyse.f_psy_trellis );
    H2( "      --no-psy                Disable all visual optimizations that worsen\n"
        "                              both PSNR and SSIM.\n" );
    H2( "      --no-mixed-refs         Don't decide references on a per partition basis\n" );
    H2( "      --no-chroma-me          Ignore chroma in motion estimation\n" );
    H1( "      --no-8x8dct             Disable adaptive spatial transform size\n" );
    H1( "  -t, --trellis <integer>     Trellis RD quantization. [%d]\n"
        "                                   - 0: disabled\n"
        "                                   - 1: enabled only on the final encode of a MB\n"
        "                                   - 2: enabled on all mode decisions\n", defaults->analyse.i_trellis );
    H2( "      --no-fast-pskip         Disables early SKIP detection on P-frames\n" );
    H2( "      --no-dct-decimate       Disables coefficient thresholding on P-frames\n" );
    H1( "      --nr <integer>          Noise reduction [%d]\n", defaults->analyse.i_noise_reduction );
    H2( "\n" );
    H2( "      --deadzone-inter <int>  Set the size of the inter luma quantization deadzone [%d]\n", defaults->analyse.i_luma_deadzone[0] );
    H2( "      --deadzone-intra <int>  Set the size of the intra luma quantization deadzone [%d]\n", defaults->analyse.i_luma_deadzone[1] );
    H2( "                                  Deadzones should be in the range 0 - 32.\n" );
    H2( "      --cqm <string>          Preset quant matrices [\"flat\"]\n"
        "                                   - jvt, flat\n" );
    H1( "      --cqmfile <string>      Read custom quant matrices from a JM-compatible file\n" );
    H2( "                                  Overrides any other --cqm* options.\n" );
    H2( "      --cqm4 <list>           Set all 4x4 quant matrices\n"
        "                                  Takes a comma-separated list of 16 integers.\n" );
    H2( "      --cqm8 <list>           Set all 8x8 quant matrices\n"
        "                                  Takes a comma-separated list of 64 integers.\n" );
    H2( "      --cqm4i, --cqm4p, --cqm8i, --cqm8p <list>\n"
        "                              Set both luma and chroma quant matrices\n" );
    H2( "      --cqm4iy, --cqm4ic, --cqm4py, --cqm4pc <list>\n"
        "                              Set individual quant matrices\n" );
    H2( "\n" );
    H2( "Video Usability Info (Annex E):\n" );
    H2( "The VUI settings are not used by the encoder but are merely suggestions to\n" );
    H2( "the playback equipment. See doc/vui.txt for details. Use at your own risk.\n" );
    H2( "\n" );
    H2( "      --overscan <string>     Specify crop overscan setting [\"%s\"]\n"
        "                                   - undef, show, crop\n",
                                        strtable_lookup( x264_overscan_names, defaults->vui.i_overscan ) );
    H2( "      --videoformat <string>  Specify video format [\"%s\"]\n"
        "                                   - component, pal, ntsc, secam, mac, undef\n",
                                        strtable_lookup( x264_vidformat_names, defaults->vui.i_vidformat ) );
    H2( "      --range <string>        Specify color range [\"%s\"]\n"
        "                                   - %s\n", range_names[0], stringify_names( buf, range_names ) );
    H2( "      --colorprim <string>    Specify color primaries [\"%s\"]\n"
        "                                   - undef, bt709, bt470m, bt470bg, smpte170m,\n"
        "                                     smpte240m, film, bt2020\n",
                                        strtable_lookup( x264_colorprim_names, defaults->vui.i_colorprim ) );
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    H2( "      --transfer <string>     Specify transfer characteristics [\"%s\"]\n"
        "                                  - undef, bt709, bt470m, bt470bg, smpte170m,\n"
        "                                    smpte240m, linear, log100, log316,\n"
        "                                    iec61966-2-4, bt1361e, iec61966-2-1,\n"
        "                                    bt2020-10, bt2020-12\n",
                                        strtable_lookup( x264_transfer_names, defaults->vui.i_transfer ) );
    H2( "      --colormatrix <string>  Specify color matrix setting [\"%s\"]\n"
        "                                  - undef, bt709, fcc, bt470bg, smpte170m,\n"
        "                                    smpte240m, GBR, YCgCo, bt2020nc, bt2020c\n",
                                        strtable_lookup( x264_colmatrix_names, defaults->vui.i_colmatrix ) );
    H2( "      --chromaloc <integer>   Specify chroma sample location (0 to 5) [%d]\n",
                                        defaults->vui.i_chroma_loc );

    H2( "      --nal-hrd <string>      Signal HRD information (requires vbv-bufsize)\n"
        "                                  - none, vbr, cbr (cbr not allowed in .mp4)\n" );
    H2( "      --filler                Force hard-CBR and generate filler (implied by\n"
        "                              --nal-hrd cbr)\n" );
    H2( "      --pic-struct            Force pic_struct in Picture Timing SEI\n" );
    H2( "      --crop-rect <string>    Add 'left,top,right,bottom' to the bitstream-level\n"
        "                              cropping rectangle\n" );

    H0( "\n" );
    H0( "Input/Output:\n" );
    H0( "\n" );
    H0( "  -o, --output <string>       Specify output file\n" );
    H1( "      --muxer <string>        Specify output container format [\"%s\"]\n"
        "                                  - %s\n", muxer_names[0], stringify_names( buf, muxer_names ) );
    H1( "      --demuxer <string>      Specify input container format [\"%s\"]\n"
        "                                  - %s\n", demuxer_names[0], stringify_names( buf, demuxer_names ) );
    H1( "      --input-fmt <string>    Specify input file format (requires lavf support)\n" );
    H1( "      --input-csp <string>    Specify input colorspace format for raw input\n" );
    print_csp_names( longhelp );
    H1( "      --output-csp <string>   Specify output colorspace [\"%s\"]\n"
        "                                  - %s\n", output_csp_names[0], stringify_names( buf, output_csp_names ) );
    H1( "      --input-depth <integer> Specify input bit depth for raw input\n" );
    H1( "      --input-range <string>  Specify input color range [\"%s\"]\n"
        "                                  - %s\n", range_names[0], stringify_names( buf, range_names ) );
    H1( "      --input-res <intxint>   Specify input resolution (width x height)\n" );
    H1( "      --index <string>        Filename for input index file\n" );
    H0( "      --sar width:height      Specify Sample Aspect Ratio\n" );
    H0( "      --fps <float|rational>  Specify framerate\n" );
    H0( "      --seek <integer>        First frame to encode\n" );
    H0( "      --frames <integer>      Maximum number of frames to encode\n" );
    H0( "      --level <string>        Specify level (as defined by Annex A)\n" );
    H1( "      --bluray-compat         Enable compatibility hacks for Blu-ray support\n" );
    H1( "      --avcintra-class <integer> Use compatibility hacks for AVC-Intra class\n"
        "                                  - 50, 100, 200\n" );
    H1( "      --stitchable            Don't optimize headers based on video content\n"
        "                              Ensures ability to recombine a segmented encode\n" );
    H1( "\n" );
    H1( "  -v, --verbose               Print stats for each frame\n" );
    H1( "      --no-progress           Don't show the progress indicator while encoding\n" );
    H0( "      --quiet                 Quiet Mode\n" );
    H1( "      --log-level <string>    Specify the maximum level of logging [\"%s\"]\n"
        "                                  - %s\n", strtable_lookup( log_level_names, cli_log_level - X264_LOG_NONE ),
                                        stringify_names( buf, log_level_names ) );
    H1( "      --psnr                  Enable PSNR computation\n" );
    H1( "      --ssim                  Enable SSIM computation\n" );
    H1( "      --threads <integer>     Force a specific number of threads\n" );
    H2( "      --lookahead-threads <integer> Force a specific number of lookahead threads\n" );
    H2( "      --sliced-threads        Low-latency but lower-efficiency threading\n" );
    H2( "      --thread-input          Run Avisynth in its own thread\n" );
    H2( "      --sync-lookahead <integer> Number of buffer frames for threaded lookahead\n" );
    H2( "      --non-deterministic     Slightly improve quality of SMP, at the cost of repeatability\n" );
    H2( "      --cpu-independent       Ensure exact reproducibility across different cpus,\n"
        "                                  as opposed to letting them select different algorithms\n" );
    H2( "      --asm <integer>         Override CPU detection\n" );
    H2( "      --no-asm                Disable all CPU optimizations\n" );
    H2( "      --opencl                Enable use of OpenCL\n" );
    H2( "      --opencl-clbin <string> Specify path of compiled OpenCL kernel cache\n" );
    H2( "      --opencl-device <integer> Specify OpenCL device ordinal\n" );
    H2( "      --dump-yuv <string>     Save reconstructed frames\n" );
    H2( "      --sps-id <integer>      Set SPS and PPS id numbers [%d]\n", defaults->i_sps_id );
    H2( "      --aud                   Use access unit delimiters\n" );
    H2( "      --force-cfr             Force constant framerate timestamp generation\n" );
    H2( "      --tcfile-in <string>    Force timestamp generation with timecode file\n" );
    H2( "      --tcfile-out <string>   Output timecode v2 file from input timestamps\n" );
    H2( "      --timebase <int/int>    Specify timebase numerator and denominator\n"
        "                  <integer>   Specify timebase numerator for input timecode file\n"
        "                              or specify timebase denominator for other input\n" );
    H2( "      --dts-compress          Eliminate initial delay with container DTS hack\n" );
    H0( "\n" );
    H0( "Filtering:\n" );
    H0( "\n" );
    H0( "      --vf, --video-filter <filter0>/<filter1>/... Apply video filtering to the input file\n" );
    H0( "\n" );
    H0( "      Filter options may be specified in <filter>:<option>=<value> format.\n" );
    H0( "\n" );
    H0( "      Available filters:\n" );
    x264_register_vid_filters();
    x264_vid_filter_help( longhelp );
    H0( "\n" );
```

```
    H0( "\n" );
}
```

help()中主要有3个宏定义：H0()，H1()和H2()。这三个宏定义实质上都是printf()。它们之间的区别在于：H0()无论如何都会调用print()；H1()在longhelp大于等于1的时候才会调用print()；而H2()在longhelp等于2时候才会调用print()。

print_version_info()

print_version_info()用于打印x264的版本信息。在x264命令行程序中添加“-V”参数后会调用该函数。该函数的定义如下所示。

[cpp]

```cpp
//打印版本信息
static void print_version_info( void )
{
#ifdef X264_POINTVER
    printf( "x264 "X264_POINTVER"\n" );
#else
    printf( "x264 0.%d.X\n", X264_BUILD );
#endif
#if HAVE_SWSCALE
    printf( "(libswscale %d.%d.%d)\n", LIBSWSCALE_VERSION_MAJOR, LIBSWSCALE_VERSION_MINOR, LIBSWSCALE_VERSION_MICRO );
#endif
#if HAVE_LAVF
    printf( "(libavformat %d.%d.%d)\n", LIBAVFORMAT_VERSION_MAJOR, LIBAVFORMAT_VERSION_MINOR, LIBAVFORMAT_VERSION_MICRO );
#endif
#if HAVE_FFMS
    printf( "(ffmpegsource %d.%d.%d.%d)\n", FFMS_VERSION >> 24, (FFMS_VERSION & 0xff0000) >> 16, (FFMS_VERSION & 0xff00) >> 8, FFMS_VERSION & 0xff);
#endif
    printf( "built on " __DATE__ ", " );
#ifdef __INTEL_COMPILER
    printf( "intel: %.2f (%d)\n", __INTEL_COMPILER / 100.f, __INTEL_COMPILER_BUILD_DATE );
#elif defined(__GNUC__)
    printf( "gcc: " __VERSION__ "\n" );
#elif defined(_MSC_FULL_VER)
    printf( "msvc: %.2f (%u)\n", _MSC_VER / 100.f, _MSC_FULL_VER );
#else
    printf( "using an unknown compiler\n" );
#endif
    printf( "configuration: --bit-depth=%d --chroma-format=%s\n", x264_bit_depth, X264_CHROMA_FORMAT ? (output_csp_names[0]+1) : "all" );
    printf( "x264 license: " );
#if HAVE_GPL
    printf( "GPL version 2 or later\n" );
#else
    printf( "Non-GPL commercial\n" );
#endif
#if HAVE_SWSCALE
    const char *license = swscale_license();
    printf( "libswscale%s%s license: %s\n", HAVE_LAVF ? "/libavformat" : "", HAVE_FFMS ? "/ffmpegsource" : "" , license );
    if( !strcmp( license, "nonfree and unredistributable" ) ||
       (!HAVE_GPL && (!strcmp( license, "GPL version 2 or later" )
                  ||  !strcmp( license, "GPL version 3 or later" ))))
        printf( "WARNING: This binary is unredistributable!\n" );
#endif
}
```

该函数定义比较浅显易懂，不再详细记录。

x264_param_parse()

x264_param_parse()是一个x264的API。该函数以字符串键值对的方式设置x264_param_t结构体的一个成员变量。该函数的声明如下所示。

[cpp]

```cpp
/* x264_param_parse:
 *  set one parameter by name.
 *  returns 0 on success, or returns one of the following errors.
 *  note: BAD_VALUE occurs only if it can't even parse the value,
 *  numerical range is not checked until x264_encoder_open() or
 *  x264_encoder_reconfig().
 *  value=NULL means "true" for boolean options, but is a BAD_VALUE for non-booleans. */
int x264_param_parse( x264_param_t *, const char *name, const char *value );
```

x264_param_parse()的定义如下所示。

x264_param_parse()中判断参数的宏OPT()和OPT2()实质上就是strcmp()。由此可见该函数的流程首先是调用strcmp()判断当前输入参数的名称name，然后再调用atoi()，atof()，或者atobool()等将当前输入参数值value转换成相应类型的值并赋值给对应的参数。

x264_param_apply_profile()

x264_param_apply_profile()是一个x264的API。该函数用于设置x264的profile，它的声明如下所示。

```
/*      (can be NULL, in which case the function will do nothing)
 *
 *      Does NOT guarantee that the given profile will be used: if the restrictions
 *      of "High" are applied to settings that are already Baseline-compatible, the
 *      stream will remain baseline.  In short, it does not increase settings, only
 *      decrease them.
 *
 *      returns 0 on success, negative on failure (e.g. invalid profile name). */
int     x264_param_apply_profile( x264_param_t *, const char *profile );
```

x264_param_apply_profile()的定义如下所示。

```
//设置profile
int x264_param_apply_profile( x264_param_t *param, const char *profile )
{
    if( !profile )
        return 0;
    //字符串到整型
    int p = profile_string_to_int( profile );
    //检查profile设置是否正确
    if( p < 0 )
    {
        x264_log( NULL, X264_LOG_ERROR, "invalid profile: %s\n", profile );
        return -1;
    }
    if( p < PROFILE_HIGH444_PREDICTIVE && ((param->rc.i_rc_method == X264_RC_CQP && param->rc.i_qp_constant <= 0) ||
        (param->rc.i_rc_method == X264_RC_CRF && (int)(param->rc.f_rf_constant + QP_BD_OFFSET) <= 0)) )
    {
        x264_log( NULL, X264_LOG_ERROR, "%s profile doesn't support lossless\n", profile );
        return -1;
    }
    if( p < PROFILE_HIGH444_PREDICTIVE && (param->i_csp & X264_CSP_MASK) >= X264_CSP_I444 )
    {
        x264_log( NULL, X264_LOG_ERROR, "%s profile doesn't support 4:4:4\n", profile );
        return -1;
    }
    if( p < PROFILE_HIGH422 && (param->i_csp & X264_CSP_MASK) >= X264_CSP_I422 )
    {
        x264_log( NULL, X264_LOG_ERROR, "%s profile doesn't support 4:2:2\n", profile );
        return -1;
    }
    if( p < PROFILE_HIGH10 && BIT_DEPTH > 8 )
    {
        x264_log( NULL, X264_LOG_ERROR, "%s profile doesn't support a bit depth of %d\n", profile, BIT_DEPTH );
        return -1;
    }
    //根据不同的Profile做设置
    //Baseline基本型
    if( p == PROFILE_BASELINE )
    {
     //不支持DCT8x8
        param->analyse.b_transform_8x8 = 0;
        //不使用CABAC
        param->b_cabac = 0;
        param->i_cqm_preset = X264_CQM_FLAT;
        param->psz_cqm_file = NULL;
        //没有B帧
        param->i_bframe = 0;
        //没有加权
        param->analyse.i_weighted_pred = X264_WEIGHTP_NONE;
        //不支持隔行扫描
        if( param->b_interlaced )
        {
            x264_log( NULL, X264_LOG_ERROR, "baseline profile doesn't support interlacing\n" );
            return -1;
        }
        if( param->b_fake_interlaced )
        {
            x264_log( NULL, X264_LOG_ERROR, "baseline profile doesn't support fake interlacing\n" );
            return -1;
        }
    }
    //Main主型
    else if( p == PROFILE_MAIN )
    {
     //不支持DCT8x8
        param->analyse.b_transform_8x8 = 0;
        param->i_cqm_preset = X264_CQM_FLAT;
        param->psz_cqm_file = NULL;
    }
    return 0;
}
```

从定义可以看出，x264_param_apply_profile()首先调用了一个函数profile_string_to_int()将输入的profile字符串转换为int类型的profile；然后会检查该profile的设置是否合理；最后会根据profile对x264_param_t中的参数进行相应的设置。

该函数中调用的profile_string_to_int()的定义如下。

```
static int profile_string_to_int( const char *str )
{
    if( !strcasecmp( str, "baseline" ) )
        return PROFILE_BASELINE;
    if( !strcasecmp( str, "main" ) )
        return PROFILE_MAIN;
    if( !strcasecmp( str, "high" ) )
        return PROFILE_HIGH;
    if( !strcasecmp( str, "high10" ) )
        return PROFILE_HIGH10;
    if( !strcasecmp( str, "high422" ) )
        return PROFILE_HIGH422;
    if( !strcasecmp( str, "high444" ) )
        return PROFILE_HIGH444_PREDICTIVE;
    return -1;
}
```

从定义可以看出profile_string_to_int()根据输入的字符串str返回不同的整型变量。

select_output()

select_output()用于设定输出的文件格式。该函数的定义如下所示。

```
//根据文件名的后缀确定输出的文件格式（raw H264，flv，mp4...）
static int select_output( const char *muxer, char *filename, x264_param_t *param )
{
    //从文件路径字符串中解析出扩展名，存入ext
    //解析的方式就是反向搜索字符“.”
    const char *ext = get_filename_extension( filename );

    //strcasecmp(char *s1, char *s2)用于忽略大小写比较字符串.
    //参数s1和s2字符串相等则返回0。s1大于s2则返回大于0 的值，s1 小于s2 则返回小于0的值。

    if( !strcmp( filename, "-" ) || strcasecmp( muxer, "auto" ) )
        ext = muxer;
    //后缀为“mp4”
    if( !strcasecmp( ext, "mp4" ) )
    {
#if HAVE_GPAC || HAVE_LSMASH
        cli_output = mp4_output;
        param->b_annexb = 0;
        param->b_repeat_headers = 0;
        if( param->i_nal_hrd == X264_NAL_HRD_CBR )
        {
            x264_cli_log( "x264", X264_LOG_WARNING, "cbr nal-hrd is not compatible with mp4\n" );
            param->i_nal_hrd = X264_NAL_HRD_VBR;
        }
#else
        x264_cli_log( "x264", X264_LOG_ERROR, "not compiled with MP4 output support\n" );
        return -1;
#endif
    }
    else if( !strcasecmp( ext, "mkv" ) )
    {
     //设定cli_output_t
        cli_output = mkv_output;
        //不加起始码0x00000001
        param->b_annexb = 0;
        //不再每个Keyframe前面加SPS和PPS
        param->b_repeat_headers = 0;
    }
    else if( !strcasecmp( ext, "flv" ) )
    {
        cli_output = flv_output;
        param->b_annexb = 0;
        param->b_repeat_headers = 0;
    }
    else
        cli_output = raw_output;//不符合上述后缀，则输出裸流
    return 0;
}
```

从函数定义可以看出，select_output()首先调用get_filename_extension()从输入文件路径的字符串中提取出了扩展名，然后根据不同的扩展名设定不同的输出格式。其

中get_filename_extension()是一个提取扩展名的函数，定义如下所示。

```
//根据“.”确定文件后缀
static inline char *get_filename_extension( char *filename )
{
    char *ext = filename + strlen( filename );
    while( *ext != '.' && ext > filename )
        ext--;
    ext += *ext == '.';
    return ext;
}
```

可以看出get_filename_extension()从字符串的末尾开始向前搜索点符号“.”，并且将“.”后面的内容作为提取出来的扩展名。

select_input()

select_input()用于设定输入的文件格式。该函数的定义如下所示。

```
//设置输入文件的格式（yuv，y4m...）
static int select_input( const char *demuxer, char *used_demuxer, char *filename,
                         hnd_t *p_handle, video_info_t *info, cli_input_opt_t *opt )
{
    int b_auto = !strcasecmp( demuxer, "auto" );
    //从文件路径字符串中解析出扩展名，存入ext
    //解析的方式就是反向搜索字符“.”
    const char *ext = b_auto ? get_filename_extension( filename ) : "";
    int b_regular = strcmp( filename, "-" );
    if( !b_regular && b_auto )
        ext = "raw";
    b_regular = b_regular && x264_is_regular_file_path( filename );
    if( b_regular )
    {
        FILE *f = x264_fopen( filename, "r" );
        if( f )
        {
            b_regular = x264_is_regular_file( f );
            fclose( f );
        }
    }
    const char *module = b_auto ? ext : demuxer;

    //strcasecmp(char *s1, char *s2)用于忽略大小写比较字符串.
    //参数s1和s2字符串相等则返回0。s1大于s2则返回大于0 的值，s1 小于s2 则返回小于0的值。

    if( !strcasecmp( module, "avs" ) || !strcasecmp( ext, "d2v" ) || !strcasecmp( ext, "dga" ) )
    {
#if HAVE_AVS
        cli_input = avs_input;
        module = "avs";
#else
        x264_cli_log( "x264", X264_LOG_ERROR, "not compiled with AVS input support\n" );
        return -1;
#endif
    }
    else if( !strcasecmp( module, "y4m" ) )
        cli_input = y4m_input;
    else if( !strcasecmp( module, "raw" ) || !strcasecmp( ext, "yuv" ) )
        cli_input = raw_input;
    else
    {
#if HAVE_FFMS
        if( b_regular && (b_auto || !strcasecmp( demuxer, "ffms" )) &&
            !ffms_input.open_file( filename, p_handle, info, opt ) )
        {
            module = "ffms";
            b_auto = 0;
            cli_input = ffms_input;
        }
#endif
#if HAVE_LAVF
        if( (b_auto || !strcasecmp( demuxer, "lavf" )) &&
            !lavf_input.open_file( filename, p_handle, info, opt ) )
        {
            module = "lavf";
            b_auto = 0;
            cli_input = lavf_input;
```

```
        }
#endif
#if HAVE_AVS
        if( b_regular && (b_auto || !strcasecmp( demuxer, "avs" )) &&
            !avs_input.open_file( filename, p_handle, info, opt ) )
        {
            module = "avs";
            b_auto = 0;
            cli_input = avs_input;
        }
#endif
        if( b_auto && !raw_input.open_file( filename, p_handle, info, opt ) )
        {
            module = "raw";
            b_auto = 0;
            cli_input = raw_input;
        }

        FAIL_IF_ERROR( !(*p_handle), "could not open input file `%s' via any method!\n", filename )
    }
    strcpy( used_demuxer, module );

    return 0;
}
```

从源代码中可以看出，select_input()首先调用get_filename_extension()获取输入文件名的扩展名；然后根据扩展名设置不同的输入格式。

至此x264命令行程序main()函数调用的parse()函数就分析完毕了。下面分析main()函数调用的另一个函数encode()。

encode()

encode()编码YUV为H.264码流，该函数的定义如下所示。

```
//编码（在内部有一个循环用于一帧一帧编码）
static int encode( x264_param_t *param, cli_opt_t *opt )
{
    x264_t *h = NULL;
    x264_picture_t pic;
    cli_pic_t cli_pic;
    const cli_pulldown_t *pulldown = NULL; // shut up gcc

    int     i_frame = 0;
    int     i_frame_output = 0;
    int64_t i_end, i_previous = 0, i_start = 0;
    int64_t i_file = 0;
    int     i_frame_size;
    int64_t last_dts = 0;
    int64_t prev_dts = 0;
    int64_t first_dts = 0;
#   define  MAX_PTS_WARNING 3 /* arbitrary */
    int     pts_warning_cnt = 0;
    int64_t largest_pts = -1;
    int64_t second_largest_pts = -1;
    int64_t ticks_per_frame;
    double  duration;
    double  pulldown_pts = 0;
    int     retval = 0;

    opt->b_progress &= param->i_log_level < X264_LOG_DEBUG;

    /* set up pulldown */
    if( opt->i_pulldown && !param->b_vfr_input )
    {
        param->b_pulldown = 1;
        param->b_pic_struct = 1;
        pulldown = &pulldown_values[opt->i_pulldown];
        param->i_timebase_num = param->i_fps_den;
        FAIL_IF_ERROR2( fmod( param->i_fps_num * pulldown->fps_factor, 1 ),
                        "unsupported framerate for chosen pulldown\n" )
        param->i_timebase_den = param->i_fps_num * pulldown->fps_factor;
    }
    //打开编码器
    h = x264_encoder_open( param );
```

```
FAIL_IF_ERROR2( !h, "x264_encoder_open failed\n" );
//获得参数
x264_encoder_parameters( h, param );
//一些不是裸流的封转格式（FLV，MP4等）需要一些参数，例如宽高等等
//cli_output_t是代表输出媒体文件的结构体
FAIL_IF_ERROR2( cli_output.set_param( opt->hout, param ), "can't set outfile param\n" );
//计时
i_start = x264_mdate();

/* ticks/frame = ticks/second / frames/second */
ticks_per_frame = (int64_t)param->i_timebase_den * param->i_fps_den / param->i_timebase_num / param->i_fps_num;
FAIL_IF_ERROR2( ticks_per_frame < 1 && !param->b_vfr_input, "ticks_per_frame invalid: %"PRId64"\n", ticks_per_frame )
ticks_per_frame = X264_MAX( ticks_per_frame, 1 );

//如果不是在每个keyframe前面都增加SPS/PPS/SEI的话，就在整个码流前面加SPS/PPS/SEI
//Header指的就是SPS/PPS/SEI
if( !param->b_repeat_headers )
{
    // Write SPS/PPS/SEI
    x264_nal_t *headers;
    int i_nal;
    //获得文件头（SPS、PPS、SEI）
    FAIL_IF_ERROR2( x264_encoder_headers( h, &headers, &i_nal ) < 0, "x264_encoder_headers failed\n" )
    //把文件头写入输出文件
    FAIL_IF_ERROR2( (i_file = cli_output.write_headers( opt->hout, headers )) < 0, "error writing headers to output file\n" );
}

if( opt->tcfile_out )
    fprintf( opt->tcfile_out, "# timecode format v2\n" );

/* Encode frames */
//循环进行编码
for( ; !b_ctrl_c && (i_frame < param->i_frame_total || !param->i_frame_total); i_frame++ )
{
 //从输入源中获取1帧YUV数据，存于cli_pic
 //cli_vid_filter_t可以认为是x264一种“扩展”后的输入源，可以在像素域对图像进行拉伸裁剪等工作。
 //原本代表输入源的结构体是cli_input_t
    if( filter.get_frame( opt->hin, &cli_pic, i_frame + opt->i_seek ) )
        break;
    //初始化x264_picture_t结构体pic
    x264_picture_init( &pic );
    //cli_pic到pic
    convert_cli_to_lib_pic( &pic, &cli_pic );

    if( !param->b_vfr_input )
        pic.i_pts = i_frame;

    if( opt->i_pulldown && !param->b_vfr_input )
    {
        pic.i_pic_struct = pulldown->pattern[ i_frame % pulldown->mod ];
        pic.i_pts = (int64_t)( pulldown_pts + 0.5 );
        pulldown_pts += pulldown_frame_duration[pic.i_pic_struct];
    }
    else if( opt->timebase_convert_multiplier )
        pic.i_pts = (int64_t)( pic.i_pts * opt->timebase_convert_multiplier + 0.5 );

    if( pic.i_pts <= largest_pts )
    {
        if( cli_log_level >= X264_LOG_DEBUG || pts_warning_cnt < MAX_PTS_WARNING )
            x264_cli_log( "x264", X264_LOG_WARNING, "non-strictly-monotonic pts at frame %d (%"PRId64" <= %"PRId64")\n",
                          i_frame, pic.i_pts, largest_pts );
        else if( pts_warning_cnt == MAX_PTS_WARNING )
            x264_cli_log( "x264", X264_LOG_WARNING, "too many nonmonotonic pts warnings, suppressing further ones\n" );
        pts_warning_cnt++;
        pic.i_pts = largest_pts + ticks_per_frame;
    }

    second_largest_pts = largest_pts;
    largest_pts = pic.i_pts;
    if( opt->tcfile_out )
        fprintf( opt->tcfile_out, "%.6f\n", pic.i_pts * ((double)param->i_timebase_num / param->i_timebase_den) * 1e3 );

    if( opt->qpfile )
        parse_qpfile( opt, &pic, i_frame + opt->i_seek );
```

```
        prev_dts = last_dts;
        //编码pic中存储的1帧YUV数据
        i_frame_size = encode_frame( h, opt->hout, &pic, &last_dts );
        if( i_frame_size < 0 )
        {
            b_ctrl_c = 1; /* lie to exit the loop */
            retval = -1;
        }
        else if( i_frame_size )
        {
            i_file += i_frame_size;
            i_frame_output++;
            if( i_frame_output == 1 )
                first_dts = prev_dts = last_dts;
        }
        //释放处理完的YUV数据
        if( filter.release_frame( opt->hin, &cli_pic, i_frame + opt->i_seek ) )
            break;

        /* update status line (up to 1000 times per input file) */
        if( opt->b_progress && i_frame_output )
            i_previous = print_status( i_start, i_previous, i_frame_output, param->i_frame_total, i_file, param, 2 * last_dts - prev_dts - first_dts );
    }
    /* Flush delayed frames */
    //输出编码器中剩余的帧
    //x264_encoder_delayed_frames()返回剩余的帧的个数
    while( !b_ctrl_c && x264_encoder_delayed_frames( h ) )
    {
        prev_dts = last_dts;
        //编码
        //注意第3个参数为NULL
        i_frame_size = encode_frame( h, opt->hout, NULL, &last_dts );
        if( i_frame_size < 0 )
        {
            b_ctrl_c = 1; /* lie to exit the loop */
            retval = -1;
        }
        else if( i_frame_size )
        {
            i_file += i_frame_size;
            i_frame_output++;
            if( i_frame_output == 1 )
                first_dts = prev_dts = last_dts;
        }
        //输出一些统计信息
        if( opt->b_progress && i_frame_output )
            i_previous = print_status( i_start, i_previous, i_frame_output, param->i_frame_total, i_file, param, 2 * last_dts - prev_dts - first_dts );
    }
fail:
    if( pts_warning_cnt >= MAX_PTS_WARNING && cli_log_level < X264_LOG_DEBUG )
        x264_cli_log( "x264", X264_LOG_WARNING, "%d suppressed nonmonotonic pts warnings\n", pts_warning_cnt-MAX_PTS_WARNING );

    /* duration algorithm fails when only 1 frame is output */
    if( i_frame_output == 1 )
        duration = (double)param->i_fps_den / param->i_fps_num;
    else if( b_ctrl_c )
        duration = (double)(2 * last_dts - prev_dts - first_dts) * param->i_timebase_num / param->i_timebase_den;
    else
        duration = (double)(2 * largest_pts - second_largest_pts) * param->i_timebase_num / param->i_timebase_den;
    //计时
    i_end = x264_mdate();
    /* Erase progress indicator before printing encoding stats. */
    if( opt->b_progress )
        fprintf( stderr, "                                                          \r" );
    //关闭编码器
    if( h )
        x264_encoder_close( h );
    fprintf( stderr, "\n" );

    if( b_ctrl_c )
        fprintf( stderr, "aborted at input frame %d, output frame %d\n", opt->i_seek + i_frame, i_frame_output );
    //关闭输出文件
    cli_output.close_file( opt->hout, largest_pts, second_largest_pts );
    opt->hout = NULL;
```

```
    if( i_frame_output > 0 )
    {
        double fps = (double)i_frame_output * (double)1000000 /
                    (double)( i_end - i_start );

        fprintf( stderr, "encoded %d frames, %.2f fps, %.2f kb/s\n", i_frame_output, fps,
                (double) i_file * 8 / ( 1000 * duration ) );
    }

    return retval;
}
```

从源代码可以梳理出来encode()的流程：

（1）调用x264_encoder_open()打开H.264编码器。

（2）调用x264_encoder_parameters()获得当前的参数集x264_param_t，用于后续步骤中的一些配置。

（3）调用输出格式（H.264裸流、FLV、mp4等）对应cli_output_t结构体的set_param()方法，为输出格式的封装器设定参数。其中参数源自于上一步骤得到的x264_param_t。

（4）如果不是在每个keyframe前面都增加SPS/PPS/SEI的话，就调用x264_encoder_headers()在整个码流前面加SPS/PPS/SEI。

（5）进入一个循环中进行一帧一帧的将YUV编码为H.264：

a)调用输入格式（YUV、Y4M等）对应的cli_vid_filter_t结构体get_frame()方法，获取一帧YUV数据。

b)调用encode_frame()编码该帧YUV数据为H.264数据，并且输出出来。该函数内部调用x264_encoder_encode()完成编码工作，调用输出格式对应cli_output_t结构体的write_frame()完成了输出工作。

c)调用输入格式（YUV、Y4M等）对应的cli_vid_filter_t结构体release_frame()方法，释放刚才获取的YUV数据。

d)调用print_status()输出一些统计信息。

（6）编码即将结束的时候，进入另一个循环，输出编码器中缓存的视频帧：

a)不再传递新的YUV数据，直接调用encode_frame()，将编码器中缓存的剩余几帧数据编码输出出来。

b)调用print_status()输出一些统计信息。

（7）调用x264_encoder_close()关闭H.264编码器。

encode()的流程中涉及到libx264的几个关键的API，在这里暂时不做详细分析（后续文章中再进行补充）：

x264_encoder_open()：打开H.264编码器。

x264_encoder_headers()：输出SPS/PPS/SEI。

x264_encoder_encode()：编码一帧数据。

x264_encoder_close()：关闭H.264编码器。

此外上述流程中涉及到两个比较简单的函数：encode_frame()和print_status()。其中encode_frame()用于编码一帧数据，而print_status()用于输出一帧数据编码后的统计信息。下文记录一下这两个函数的定义。

encode_frame()

encode_frame()的定义如下。

```
//编码1帧
static int encode_frame( x264_t *h, hnd_t hout, x264_picture_t *pic, int64_t *last_dts )
{
    x264_picture_t pic_out;
    x264_nal_t *nal;
    int i_nal;
    int i_frame_size = 0;
    //编码API
    //编码x264_picture_t为x264_nal_t
    i_frame_size = x264_encoder_encode( h, &nal, &i_nal, pic, &pic_out );

    FAIL_IF_ERROR( i_frame_size < 0, "x264_encoder_encode failed\n" );

    if( i_frame_size )
    {
     //通过cli_output_t中的方法输出
     //输出raw H.264流的话，等同于直接fwrite()
     //其他封装格式，则还需进行一定的封装
        i_frame_size = cli_output.write_frame( hout, nal[0].p_payload, i_frame_size, &pic_out );
        *last_dts = pic_out.i_dts;
    }

    return i_frame_size;
}
```

从源代码可以看出，encode_frame()内部调用x264_encoder_encode()完成编码工作，调用输出格式对应cli_output_t结构体的write_frame()完成了输出工作。其中有关c

li_output_t结构体的知识将在后文中记录。

print_status()

print_status()的定义如下。

```
//打印一些和时间有关的统计信息
static int64_t print_status( int64_t i_start, int64_t i_previous, int i_frame, int i_frame_total, int64_t i_file, x264_param_t *param, int64_t last_ts )
{
    char buf[200];
    int64_t i_time = x264_mdate();
    if( i_previous && i_time - i_previous < UPDATE_INTERVAL )
        return i_previous;
    int64_t i_elapsed = i_time - i_start;
    double fps = i_elapsed > 0 ? i_frame * 1000000. / i_elapsed : 0;
    double bitrate;
    if( last_ts )
        bitrate = (double) i_file * 8 / ( (double) last_ts * 1000 * param->i_timebase_num / param->i_timebase_den );
    else
        bitrate = (double) i_file * 8 / ( (double) 1000 * param->i_fps_den / param->i_fps_num );
    if( i_frame_total )
    {
     //形成输出的字符串
        int eta = i_elapsed * (i_frame_total - i_frame) / ((int64_t)i_frame * 1000000);
        sprintf( buf, "x264 [%.1f%%] %d/%d frames, %.2f fps, %.2f kb/s, eta %d:%02d:%02d",
                100. * i_frame / i_frame_total, i_frame, i_frame_total, fps, bitrate,
                eta/3600, (eta/60)%60, eta%60 );
    }
    else
        sprintf( buf, "x264 %d frames: %.2f fps, %.2f kb/s", i_frame, fps, bitrate );
    //输出到stderr
    fprintf( stderr, "%s  \r", buf+5 );
    //设置到标题栏？
    x264_cli_set_console_title( buf );
    fflush( stderr ); // needed in windows
    return i_time;
}
```

print_status()的代码不再详细记录，它的输出效果如下图中红框中的文字。

X264控制台程序中和输入输出相关的结构体

在x264控制台程序中有3个和输入输出相关的结构体：

cli_output_t：输出格式对应的结构体。输出格式一般为H.264裸流、FLV、MP4等。

cli_input_t：输入格式对应的结构体。输入格式一般为纯YUV像素数据，Y4M格式数据等。

cli_vid_filter_t：输入格式滤镜结构体。滤镜可以对输入数据做一些简单的处理，例如拉伸、裁剪等等（当然滤镜也可以不作任何处理，直接读取输入数据）。

在x264的编码过程中，调用cli_vid_filter_t结构体的get_frame()读取YUV数据，调用cli_output_t的write_frame()写入数据。下面简单分析一下它们之间的关系。

cli_output_t

x264项目中和cli_output_t结构体相关的源代码都位于根目录的output文件夹下。cli_output_t的定义位于output\output.h，如下所示。

```
typedef struct
{
    int (*open_file)( char *psz_filename, hnd_t *p_handle, cli_output_opt_t *opt );
    int (*set_param)( hnd_t handle, x264_param_t *p_param );
    int (*write_headers)( hnd_t handle, x264_nal_t *p_nal );
    int (*write_frame)( hnd_t handle, uint8_t *p_nal, int i_size, x264_picture_t *p_picture );
    int (*close_file)( hnd_t handle, int64_t largest_pts, int64_t second_largest_pts );
} cli_output_t;

extern const cli_output_t raw_output;
extern const cli_output_t mkv_output;
extern const cli_output_t mp4_output;
extern const cli_output_t flv_output;
```

从源代码中可以看出，cli_output_t中一共包含了open_file()，set_param()，write_headers()，write_frame()，close_file()五个接口。在x264中有raw_output，mkv_output，mp4_output，flv_output这几个cli_output_t结构体，分别对应H.264裸流，MKV，MP4，FLV格式。下面举例看两个结构体：raw_output和flv_output。

raw_output（H.264裸流的cli_output_t结构体）

raw_output的定义位于output\raw.c，该文件内容如下所示。

```
#include "output.h"

static int open_file( char *psz_filename, hnd_t *p_handle, cli_output_opt_t *opt )
{
    if( !strcmp( psz_filename, "-" ) )
        *p_handle = stdout;
    else if( !(*p_handle = x264_fopen( psz_filename, "w+b" )) )
        return -1;

    return 0;
}

static int set_param( hnd_t handle, x264_param_t *p_param )
{
    return 0;
}

static int write_headers( hnd_t handle, x264_nal_t *p_nal )
{
    int size = p_nal[0].i_payload + p_nal[1].i_payload + p_nal[2].i_payload;

    if( fwrite( p_nal[0].p_payload, size, 1, (FILE*)handle ) )
        return size;
    return -1;
}

static int write_frame( hnd_t handle, uint8_t *p_nalu, int i_size, x264_picture_t *p_picture )
{
    if( fwrite( p_nalu, i_size, 1, (FILE*)handle ) )
        return i_size;
    return -1;
}

static int close_file( hnd_t handle, int64_t largest_pts, int64_t second_largest_pts )
{
    if( !handle || handle == stdout )
        return 0;

    return fclose( (FILE*)handle );
}

const cli_output_t raw_output = { open_file, set_param, write_headers, write_frame, close_file };
```

可以看出raw_output中的函数定义都比较简单，只是封装了fwrite()，fclose()等函数。

flv_output（FLV格式的cli_output_t结构体）

flv_output的定义位于output\flv.c，如下所示。

```
const cli_output_t flv_output = { open_file, set_param, write_headers, write_frame, close_file };
```

该文件内容比较多，只举例看一下其中的两个函数：open_file()和write_frame()。

open_file()

flv_output 中的open_file()的定义如下所示。

```
static int write_header( flv_buffer *c )
{
    flv_put_tag( c, "FLV" ); // Signature
    flv_put_byte( c, 1 );    // Version
    flv_put_byte( c, 1 );    // Video Only
    flv_put_be32( c, 9 );    // DataOffset
    flv_put_be32( c, 0 );    // PreviousTagSize0

    return flv_flush_data( c );
}

static int open_file( char *psz_filename, hnd_t *p_handle, cli_output_opt_t *opt )
{
    *p_handle = NULL;
    flv_hnd_t *p_flv = calloc( 1, sizeof(flv_hnd_t) );
    if( !p_flv )
        return -1;

    p_flv->b_dts_compress = opt->use_dts_compress;

    p_flv->c = flv_create_writer( psz_filename );
    if( !p_flv->c )
        return -1;

    CHECK( write_header( p_flv->c ) );
    *p_handle = p_flv;

    return 0;
}
```

可以看出flv_output 中的open_file()中完成了FLV封装格式文件头的创建。

write_frame()

flv_output 中的write_frame()的定义如下所示。

```
static int write_frame( hnd_t handle, uint8_t *p_nalu, int i_size, x264_picture_t *p_picture )
{
    flv_hnd_t *p_flv = handle;
    flv_buffer *c = p_flv->c;

#define convert_timebase_ms( timestamp, timebase ) (int64_t)((timestamp) * (timebase) * 1000 + 0.5)

    if( !p_flv->i_framenum )
    {
        p_flv->i_delay_time = p_picture->i_dts * -1;
        if( !p_flv->b_dts_compress && p_flv->i_delay_time )
            x264_cli_log( "flv", X264_LOG_INFO, "initial delay %"PRId64" ms\n",
                          convert_timebase_ms( p_picture->i_pts + p_flv->i_delay_time, p_flv->d_timebase ) );
    }

    int64_t dts;
    int64_t cts;
    int64_t offset;

    if( p_flv->b_dts_compress )
    {
        if( p_flv->i_framenum == 1 )
            p_flv->i_init_delta = convert_timebase_ms( p_picture->i_dts + p_flv->i_delay_time, p_flv->d_timebase );
        dts = p_flv->i_framenum > p_flv->i_delay_frames
            ? convert_timebase_ms( p_picture->i_dts, p_flv->d_timebase )
            : p_flv->i_framenum * p_flv->i_init_delta / (p_flv->i_delay_frames + 1);
        cts = convert_timebase_ms( p_picture->i_pts, p_flv->d_timebase );
    }
    else
    {
        dts = convert_timebase_ms( p_picture->i_dts + p_flv->i_delay_time, p_flv->d_timebase );
        cts = convert_timebase_ms( p_picture->i_pts + p_flv->i_delay_time, p_flv->d_timebase );
    }
    offset = cts - dts;

    if( p_flv->i_framenum )
    {
        if( p_flv->i_prev_dts == dts )
            x264_cli_log( "flv", X264_LOG_WARNING, "duplicate DTS %"PRId64" generated by rounding\n"
                          "              decoding framerate cannot exceed 1000fps\n", dts );
        if( p_flv->i_prev_dts == cts )
```

```
    if( p_flv->i_prev_cts == cts )
        x264_cli_log( "flv", X264_LOG_WARNING, "duplicate CTS %"PRId64" generated by rounding\n"
                      "                 composition framerate cannot exceed 1000fps\n", cts );
    }
    p_flv->i_prev_dts = dts;
    p_flv->i_prev_cts = cts;

    // A new frame - write packet header
    flv_put_byte( c, FLV_TAG_TYPE_VIDEO );
    flv_put_be24( c, 0 ); // calculated later
    flv_put_be24( c, dts );
    flv_put_byte( c, dts >> 24 );
    flv_put_be24( c, 0 );

    p_flv->start = c->d_cur;
    flv_put_byte( c, p_picture->b_keyframe ? FLV_FRAME_KEY : FLV_FRAME_INTER );
    flv_put_byte( c, 1 ); // AVC NALU
    flv_put_be24( c, offset );

    if( p_flv->sei )
    {
        flv_append_data( c, p_flv->sei, p_flv->sei_len );
        free( p_flv->sei );
        p_flv->sei = NULL;
    }
    flv_append_data( c, p_nalu, i_size );

    unsigned length = c->d_cur - p_flv->start;
    flv_rewrite_amf_be24( c, length, p_flv->start - 10 );
    flv_put_be32( c, 11 + length ); // Last tag size
    CHECK( flv_flush_data( c ) );

    p_flv->i_framenum++;

    return i_size;
}
```

flv_output 中的可以看出write_frame()中完成了FLV封装格式中一个Tag单元的创建。

cli_input_t

x264项目中和cli_input_t结构体相关的源代码都位于根目录的input文件夹下。cli_input_t的定义位于input\input.h，如下所示。

```
typedef struct
{
    int (*open_file)( char *psz_filename, hnd_t *p_handle, video_info_t *info, cli_input_opt_t *opt );
    int (*picture_alloc)( cli_pic_t *pic, int csp, int width, int height );
    int (*read_frame)( cli_pic_t *pic, hnd_t handle, int i_frame );
    int (*release_frame)( cli_pic_t *pic, hnd_t handle );
    void (*picture_clean)( cli_pic_t *pic );
    int (*close_file)( hnd_t handle );
} cli_input_t;

extern const cli_input_t raw_input;
extern const cli_input_t y4m_input;
extern const cli_input_t avs_input;
extern const cli_input_t lavf_input;
extern const cli_input_t ffms_input;
```

从源代码中可以看出，cli_input_t中一共包含了open_file()，picture_alloc()，read_frame()，release_frame()，picture_clean()，close_file()六个接口。在x264中有raw_input，y4m_input，avs_input，lavf_input，ffms_input这几个cli_output_t结构体，分别对应H.264裸流，Y4M，AVS，LAVF，FFMS格式（后几种没有接触过）。下面举例看两个结构体：raw_input和y4m_input。

raw_input（纯YUV像素数据的cli_input_t结构体）

raw_input的定义位于input\raw.c，该文件内容如下所示。

```
#include "input.h"
#define FAIL_IF_ERROR( cond, ... ) FAIL_IF_ERR( cond, "raw", __VA_ARGS__ )

typedef struct
{
    FILE *fh;
    int next_frame;
    uint64_t plane_size[4];
    uint64_t frame_size;
```

```
    uint64_t frame_size;
    int bit_depth;
} raw_hnd_t;

//打开raw YUV格式文件
static int open_file( char *psz_filename, hnd_t *p_handle, video_info_t *info, cli_input_opt_t *opt )
{
    raw_hnd_t *h = calloc( 1, sizeof(raw_hnd_t) );
    if( !h )
        return -1;

    if( !opt->resolution )
    {
     //如果没有设置分辨率
     //尝试从文件名中解析分辨率
        /* try to parse the file name */
        for( char *p = psz_filename; *p; p++ )
            if( *p >= '0' && *p <= '9' && sscanf( p, "%dx%d", &info->width, &info->height ) == 2 )
                break;
    }
    else
        sscanf( opt->resolution, "%dx%d", &info->width, &info->height );
    //没有分辨率信息的话，会弹出错误信息
    FAIL_IF_ERROR( !info->width || !info->height, "raw input requires a resolution.\n" )
    //设置颜色空间
    if( opt->colorspace )
    {
        for( info->csp = X264_CSP_CLI_MAX-1; info->csp > X264_CSP_NONE; info->csp-- )
        {
            if( x264_cli_csps[info->csp].name && !strcasecmp( x264_cli_csps[info->csp].name, opt->colorspace ) )
                break;
        }
        FAIL_IF_ERROR( info->csp == X264_CSP_NONE, "unsupported colorspace `%s'\n", opt->colorspace );
    }
    else /* default */
        info->csp = X264_CSP_I420;//默认为YUV420P
    //颜色位深
    h->bit_depth = opt->bit_depth;
    FAIL_IF_ERROR( h->bit_depth < 8 || h->bit_depth > 16, "unsupported bit depth `%d'\n", h->bit_depth );
    if( h->bit_depth > 8 )
        info->csp |= X264_CSP_HIGH_DEPTH;

    if( !strcmp( psz_filename, "-" ) )
        h->fh = stdin;  //从管道输入
    else
        h->fh = x264_fopen( psz_filename, "rb" );  //打开文件
    if( h->fh == NULL )
        return -1;

    info->thread_safe = 1;
    info->num_frames  = 0;
    info->vfr         = 0;

    const x264_cli_csp_t *csp = x264_cli_get_csp( info->csp );
    for( int i = 0; i < csp->planes; i++ )
    {
        h->plane_size[i] = x264_cli_pic_plane_size( info->csp, info->width, info->height, i );
        h->frame_size += h->plane_size[i];
        /* x264_cli_pic_plane_size returns the size in bytes, we need the value in pixels from here on */
        h->plane_size[i] /= x264_cli_csp_depth_factor( info->csp );
    }

    if( x264_is_regular_file( h->fh ) )
    {
        fseek( h->fh, 0, SEEK_END );
        uint64_t size = ftell( h->fh );
        fseek( h->fh, 0, SEEK_SET );
        info->num_frames = size / h->frame_size;
    }

    *p_handle = h;
    return 0;
}

//读取一帧数据-内部
```

```
static int read_frame_internal( cli_pic_t *pic, raw_hnd_t *h, int bit_depth_uc )
{
    int error = 0;
    int pixel_depth = x264_cli_csp_depth_factor( pic->img.csp );
    //一个分量一个分量读
    for( int i = 0; i < pic->img.planes && !error; i++ )
    {
     //fread()读取
        error |= fread( pic->img.plane[i], pixel_depth, h->plane_size[i], h->fh ) != h->plane_size[i];
        if( bit_depth_uc )
        {
            /* upconvert non 16bit high depth planes to 16bit using the same
             * algorithm as used in the depth filter. */
            uint16_t *plane = (uint16_t*)pic->img.plane[i];
            uint64_t pixel_count = h->plane_size[i];
            int lshift = 16 - h->bit_depth;
            for( uint64_t j = 0; j < pixel_count; j++ )
                plane[j] = plane[j] << lshift;
        }
    }
    return error;
}
//读取一帧数据
static int read_frame( cli_pic_t *pic, hnd_t handle, int i_frame )
{
    raw_hnd_t *h = handle;

    if( i_frame > h->next_frame )
    {
        if( x264_is_regular_file( h->fh ) )
            fseek( h->fh, i_frame * h->frame_size, SEEK_SET );  //fseek()。偏移量=帧序号*帧大小。
        else
            while( i_frame > h->next_frame )
            {
             //读取一帧数据-内部
                if( read_frame_internal( pic, h, 0 ) )
                    return -1;
                h->next_frame++;
            }
    }

    if( read_frame_internal( pic, h, h->bit_depth & 7 ) )
        return -1;

    h->next_frame = i_frame+1;
    return 0;
}

//关闭文件
static int close_file( hnd_t handle )
{
    raw_hnd_t *h = handle;
    if( !h || !h->fh )
        return 0;
    //fclose()关闭文件
    fclose( h->fh );
    free( h );
    return 0;
}
//raw格式对应的数组
const cli_input_t raw_input = { open_file, x264_cli_pic_alloc, read_frame, NULL, x264_cli_pic_clean, close_file };
```

从源代码中可以看出，raw_input　中的open_file()函数在打开YUV像素数据的时候，会首先判断是否设置了宽和高（YUV是纯像素数据，没有宽和高信息），如果没有设置，则会尝试从文件路径中解析宽和高信息。如果成功完成上述步骤，open_file()就会调用x264_fopen()打开输入文件。其他的函数在源代码中都写了注释，就不再重复记录了。

y4m_input（Y4M格式的cli_input_t结构体）

y4m_input的定义位于input\y4m.c，如下所示。

```
const cli_input_t y4m_input = { open_file, x264_cli_pic_alloc, read_frame, NULL, x264_cli_pic_clean, close_file };
```

该文件内容较多，不再进行详细分析。在这里看一个打开文件的函数open_file()。该函数的定义如下所示。

```
typedef struct
{
    FILE *fh;
    int next_frame;
    int seq_header_len;
    int frame_header_len;
    uint64_t frame_size;
    uint64_t plane_size[3];
    int bit_depth;
} y4m_hnd_t;

#define Y4M_MAGIC "YUV4MPEG2"
#define MAX_YUV4_HEADER 80
#define Y4M_FRAME_MAGIC "FRAME"
#define MAX_FRAME_HEADER 80

static int parse_csp_and_depth( char *csp_name, int *bit_depth )
{
    int csp    = X264_CSP_MAX;

    /* Set colorspace from known variants */
    if( !strncmp( "420", csp_name, 3 ) )
        csp = X264_CSP_I420;
    else if( !strncmp( "422", csp_name, 3 ) )
        csp = X264_CSP_I422;
    else if( !strncmp( "444", csp_name, 3 ) && strncmp( "444alpha", csp_name, 8 ) ) // only accept alphaless 4:4:4
        csp = X264_CSP_I444;

    /* Set high bit depth from known extensions */
    if( sscanf( csp_name, "%*d%*[pP]%d", bit_depth ) != 1 )
        *bit_depth = 8;

    return csp;
}

static int open_file( char *psz_filename, hnd_t *p_handle, video_info_t *info, cli_input_opt_t *opt )
{
    y4m_hnd_t *h = malloc( sizeof(y4m_hnd_t) );
    int i;
    uint32_t n, d;
    char header[MAX_YUV4_HEADER+10];
    char *tokend, *header_end;
    int colorspace = X264_CSP_NONE;
    int alt_colorspace = X264_CSP_NONE;
    int alt_bit_depth  = 8;
    if( !h )
        return -1;

    h->next_frame = 0;
    info->vfr = 0;

    if( !strcmp( psz_filename, "-" ) )
        h->fh = stdin;
    else
        h->fh = x264_fopen(psz_filename, "rb");
    if( h->fh == NULL )
        return -1;

    h->frame_header_len = strlen( Y4M_FRAME_MAGIC )+1;

    /* Read header */
    //解析Y4M格式的文件头
    for( i = 0; i < MAX_YUV4_HEADER; i++ )
    {
        header[i] = fgetc( h->fh );
        if( header[i] == '\n' )
        {
            /* Add a space after last option. Makes parsing "444" vs
               "444alpha" easier. */
            header[i+1] = 0x20;
            header[i+2] = 0;
            break;
        }
    }
    if( i == MAX_YUV4_HEADER || strncmp( header, Y4M_MAGIC, strlen( Y4M_MAGIC ) ) )
```

```
    return -1;

/* Scan properties */
header_end = &header[i+1]; /* Include space */
h->seq_header_len = i+1;
for( char *tokstart = &header[strlen( Y4M_MAGIC )+1]; tokstart < header_end; tokstart++ )
{
    if( *tokstart == 0x20 )
        continue;
    switch( *tokstart++ )
    {
        case 'W': /* Width. Required. */
            info->width = strtol( tokstart, &tokend, 10 );
            tokstart=tokend;
            break;
        case 'H': /* Height. Required. */
            info->height = strtol( tokstart, &tokend, 10 );
            tokstart=tokend;
            break;
        case 'C': /* Color space */
            colorspace = parse_csp_and_depth( tokstart, &h->bit_depth );
            tokstart = strchr( tokstart, 0x20 );
            break;
        case 'I': /* Interlace type */
            switch( *tokstart++ )
            {
                case 't':
                    info->interlaced = 1;
                    info->tff = 1;
                    break;
                case 'b':
                    info->interlaced = 1;
                    info->tff = 0;
                    break;
                case 'm':
                    info->interlaced = 1;
                    break;
                //case '?':
                //case 'p':
                default:
                    break;
            }
            break;
        case 'F': /* Frame rate - 0:0 if unknown */
            if( sscanf( tokstart, "%u:%u", &n, &d ) == 2 && n && d )
            {
                x264_reduce_fraction( &n, &d );
                info->fps_num = n;
                info->fps_den = d;
            }
            tokstart = strchr( tokstart, 0x20 );
            break;
        case 'A': /* Pixel aspect - 0:0 if unknown */
            /* Don't override the aspect ratio if sar has been explicitly set on the commandline. */
            if( sscanf( tokstart, "%u:%u", &n, &d ) == 2 && n && d )
            {
                x264_reduce_fraction( &n, &d );
                info->sar_width  = n;
                info->sar_height = d;
            }
            tokstart = strchr( tokstart, 0x20 );
            break;
        case 'X': /* Vendor extensions */
            if( !strncmp( "YSCSS=", tokstart, 6 ) )
            {
                /* Older nonstandard pixel format representation */
                tokstart += 6;
                alt_colorspace = parse_csp_and_depth( tokstart, &alt_bit_depth );
            }
            tokstart = strchr( tokstart, 0x20 );
            break;
    }
}

if( colorspace == X264_CSP_NONE )
```

```
    if( colorspace == X264_CSP_NONE )
    {
        colorspace   = alt_colorspace;
        h->bit_depth = alt_bit_depth;
    }

    // default to 8bit 4:2:0 if nothing is specified
    if( colorspace == X264_CSP_NONE )
    {
        colorspace    = X264_CSP_I420;
        h->bit_depth  = 8;
    }

    FAIL_IF_ERROR( colorspace <= X264_CSP_NONE || colorspace >= X264_CSP_MAX, "colorspace unhandled\n" )
    FAIL_IF_ERROR( h->bit_depth < 8 || h->bit_depth > 16, "unsupported bit depth `%d'\n", h->bit_depth );

    info->thread_safe = 1;
    info->num_frames  = 0;
    info->csp         = colorspace;
    h->frame_size     = h->frame_header_len;

    if( h->bit_depth > 8 )
        info->csp |= X264_CSP_HIGH_DEPTH;

    const x264_cli_csp_t *csp = x264_cli_get_csp( info->csp );

    for( i = 0; i < csp->planes; i++ )
    {
        h->plane_size[i] = x264_cli_pic_plane_size( info->csp, info->width, info->height, i );
        h->frame_size += h->plane_size[i];
        /* x264_cli_pic_plane_size returns the size in bytes, we need the value in pixels from here on */
        h->plane_size[i] /= x264_cli_csp_depth_factor( info->csp );
    }

    /* Most common case: frame_header = "FRAME" */
    if( x264_is_regular_file( h->fh ) )
    {
        uint64_t init_pos = ftell( h->fh );
        fseek( h->fh, 0, SEEK_END );
        uint64_t i_size = ftell( h->fh );
        fseek( h->fh, init_pos, SEEK_SET );
        info->num_frames = (i_size - h->seq_header_len) / h->frame_size;
    }

    *p_handle = h;
    return 0;
}
```

从源代码可以看出，y4m_input中的open_file()完成了Y4M文件的打开和文件头解析的功能。

cli_vid_filter_t

x264项目中和cli_vid_filter_t结构体相关的源代码都位于根目录的filters文件夹下。cli_vid_filter_t的定义位于filters\video\video.h，如下所示。

```
struct cli_vid_filter_t
{
    /* name of the filter */
    const char *name;
    /* help: a short message on what the filter does and how to use it.
     * this should only be implemented by filters directly accessible by the user */
    void (*help)( int longhelp );
    /* init: initializes the filter given the input clip properties and parameter to adjust them as necessary
     * with the given options provided by the user.
     * returns 0 on success, nonzero on error. */
    int (*init)( hnd_t *handle, cli_vid_filter_t *filter, video_info_t *info, x264_param_t *param, char *opt_string );
    /* get_frame: given the storage for the output frame and desired frame number, generate the frame accordingly.
     * the image data returned by get_frame should be treated as const and not be altered.
     * returns 0 on success, nonzero on error. */
    int (*get_frame)( hnd_t handle, cli_pic_t *output, int frame );
    /* release_frame: frame is done being used and is signaled for cleanup.
     * returns 0 on succeess, nonzero on error. */
    int (*release_frame)( hnd_t handle, cli_pic_t *pic, int frame );
    /* free: run filter cleanup procedures. */
    void (*free)( hnd_t handle );
    /* next registered filter, unused by filters themselves */
    cli_vid_filter_t *next;
};
```

从源代码中可以看出，cli_vid_filter_t中一共包含了help()，init()，get_frame()，release_frame()，free()几个接口。下面举例看两个Filter结构体：

source_filter：不作任何处理。

resize_filter：拉伸。

source_filter（没有功能的cli_vid_filter_t结构体）

source_filter的定义位于filters\video\source.c，该文件内容如下所示。

```
#include "video.h"

/* This filter converts the demuxer API into the filtering API for video frames.
 * Backseeking is prohibited here as not all demuxers are capable of doing so. */

typedef struct
{
    cli_pic_t pic;
    hnd_t hin;
    int cur_frame;
} source_hnd_t;

cli_vid_filter_t source_filter;

static int init( hnd_t *handle, cli_vid_filter_t *filter, video_info_t *info, x264_param_t *param, char *opt_string )
{
    source_hnd_t *h = calloc( 1, sizeof(source_hnd_t) );
    if( !h )
        return -1;
    h->cur_frame = -1;

    if( cli_input.picture_alloc( &h->pic, info->csp, info->width, info->height ) )
        return -1;

    h->hin = *handle;
    *handle = h;
    *filter = source_filter;

    return 0;
}

static int get_frame( hnd_t handle, cli_pic_t *output, int frame )
{
    source_hnd_t *h = handle;
    /* do not allow requesting of frames from before the current position */
    if( frame <= h->cur_frame || cli_input.read_frame( &h->pic, h->hin, frame ) )
        return -1;
    h->cur_frame = frame;
    *output = h->pic;
    return 0;
}

static int release_frame( hnd_t handle, cli_pic_t *pic, int frame )
{
    source_hnd_t *h = handle;
    if( cli_input.release_frame && cli_input.release_frame( &h->pic, h->hin ) )
        return -1;
    return 0;
}

static void free_filter( hnd_t handle )
{
    source_hnd_t *h = handle;
    cli_input.picture_clean( &h->pic );
    cli_input.close_file( h->hin );
    free( h );
}

cli_vid_filter_t source_filter = { "source", NULL, init, get_frame, release_frame, free_filter, NULL };
```

从源代码中可以看出，source_filter的get_frame()直接调用了cli_input_t的read_frame()；而它的release_frame()也是直接调用了cli_input_t的release_frame()。简而言之，source_filter相当于是一个cli_input_t。

resize_filter（拉伸功能对应的cli_vid_filter_t结构体）

resize_filter的定义位于filters\video\resize.c，该结构体定义如下。

```
cli_vid_filter_t resize_filter = { NAME, help, init, get_frame, release_frame, free_filter, NULL };
```

由于resize_filter涉及到的代码比较多，在这里仅看一下它的get_frame()的定义。

```
static int get_frame( hnd_t handle, cli_pic_t *output, int frame )
{
    resizer_hnd_t *h = handle;
    if( h->prev_filter.get_frame( h->prev_hnd, output, frame ) )
        return -1;
    if( h->variable_input && check_resizer( h, output ) )
        return -1;
    h->working = 1;
    if( h->pre_swap_chroma )
        XCHG( uint8_t*, output->img.plane[1], output->img.plane[2] );
    if( h->ctx )
    {
        sws_scale( h->ctx, (const uint8_t* const*)output->img.plane, output->img.stride,
                   0, output->img.height, h->buffer.img.plane, h->buffer.img.stride );
        output->img = h->buffer.img; /* copy img data */
    }
    else
        output->img.csp = h->dst_csp;
    if( h->post_swap_chroma )
        XCHG( uint8_t*, output->img.plane[1], output->img.plane[2] );

    return 0;
}
```

可以看出resize_filter中调用了libswscale类库中的sws_scale()对图像完成了拉伸工作。
注：拉伸滤镜需要libswscale类库的支持。

至此cli_output_t，cli_input_t，cli_vid_filter_t这3个在x264中与输入输出有关的结构体的源代码就分析完毕了。有关x264命令行工具的源代码分析工作也就做完了。下一篇文章开始对libx264内部的源代码进行分析。

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