原 FFMPEG结构体分析：AVFrame

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注：写了一系列的结构体的分析的文章，在这里列一个列表：

FFMPEG结构体分析：AVFrame

FFMPEG结构体分析：AVFormatContext

FFMPEG结构体分析：AVCodecContext

FFMPEG结构体分析：AVIOContext

FFMPEG结构体分析：AVCodec

FFMPEG结构体分析：AVStream

FFMPEG结构体分析：AVPacket

FFMPEG有几个最重要的结构体，包含了解协议，解封装，解码操作，此前已经进行过分析：

FFMPEG中最关键的结构体之间的关系

在此不再详述，其中AVFrame是包含码流参数较多的结构体。本文将会详细分析一下该结构体里主要变量的含义和作用。

首先看一下结构体的定义（位于avcodec.h）：

```cpp
/*
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 */
/**
 * Audio Video Frame.
 * New fields can be added to the end of AVFRAME with minor version
 * bumps. Similarly fields that are marked as to be only accessed by
 * av_opt_ptr() can be reordered. This allows 2 forks to add fields
 * without breaking compatibility with each other.
 * Removal, reordering and changes in the remaining cases require
 * a major version bump.
 * sizeof(AVFrame) must not be used outside libavcodec.
 */
typedef struct AVFrame {
#define AV_NUM_DATA_POINTERS 8
    /**图像数据
     * pointer to the picture/channel planes.
     * This might be different from the first allocated byte
     * - encoding: Set by user
     * - decoding: set by AVCodecContext.get_buffer()
     */
    uint8_t *data[AV_NUM_DATA_POINTERS];

    /**
     * Size, in bytes, of the data for each picture/channel plane.
     *
     * For audio, only linesize[0] may be set. For planar audio, each channel
     * plane must be the same size.
     *
     * - encoding: Set by user
     * - decoding: set by AVCodecContext.get_buffer()
     */
    int linesize[AV_NUM_DATA_POINTERS];

    /**
     * pointers to the data planes/channels.
     *
     * For video, this should simply point to data[].
     *
     * For planar audio, each channel has a separate data pointer, and
     * linesize[0] contains the size of each channel buffer.
     * For packed audio, there is just one data pointer, and linesize[0]
     * contains the total size of the buffer for all channels.
     *
     * Note: Both data and extended_data will always be set by get_buffer(),
     * but for planar audio with more channels that can fit in data,
     * extended_data must be used by the decoder in order to access all
     * channels.
     *
     * encoding: unused
     * decoding: set by AVCodecContext.get_buffer()
     */
    uint8_t **extended_data;

```

```
    /**宽高
     * width and height of the video frame
     * - encoding: unused
     * - decoding: Read by user.
     */
    int width, height;

    /**
     * number of audio samples (per channel) described by this frame
     * - encoding: Set by user
     * - decoding: Set by libavcodec
     */
    int nb_samples;

    /**
     * format of the frame, -1 if unknown or unset
     * Values correspond to enum AVPixelFormat for video frames,
     * enum AVSampleFormat for audio)
     * - encoding: unused
     * - decoding: Read by user.
     */
    int format;

    /**是否是关键帧
     * 1 -> keyframe, 0-> not
     * - encoding: Set by libavcodec.
     * - decoding: Set by libavcodec.
     */
    int key_frame;

    /**帧类型（I,B,P)
     * Picture type of the frame, see ?_TYPE below.
     * - encoding: Set by libavcodec. for coded_picture (and set by user for input).
     * - decoding: Set by libavcodec.
     */
    enum AVPictureType pict_type;

    /**
     * pointer to the first allocated byte of the picture. Can be used in get_buffer/release_buffer.
     * This isn't used by libavcodec unless the default get/release_buffer() is used.
     * - encoding:
     * - decoding:
     */
    uint8_t *base[AV_NUM_DATA_POINTERS];

    /**
     * sample aspect ratio for the video frame, 0/1 if unknown/unspecified
     * - encoding: unused
     * - decoding: Read by user.
     */
    AVRational sample_aspect_ratio;

    /**
     * presentation timestamp in time_base units (time when frame should be shown to user)
     * If AV_NOPTS_VALUE then frame_rate = 1/time_base will be assumed.
     * - encoding: MUST be set by user.
     * - decoding: Set by libavcodec.
     */
    int64_t pts;

    /**
     * reordered pts from the last AVPacket that has been input into the decoder
     * - encoding: unused
     * - decoding: Read by user.
     */
    int64_t pkt_pts;

    /**
     * dts from the last AVPacket that has been input into the decoder
     * - encoding: unused
     * - decoding: Read by user.
     */
    int64_t pkt_dts;

    /**
     * picture number in bitstream order
     * - encoding: set by
     * - decoding: Set by libavcodec.
     */
    int coded_picture_number;
    /**
     * picture number in display order
     * - encoding: set by
     * - decoding: Set by libavcodec.
     */
    int display_picture_number;

    /**
     * quality (between 1 (good) and FF_LAMBDA_MAX (bad))
     * - encoding: Set by libavcodec. for coded_picture (and set by user for input).
     * - decoding: Set by libavcodec.
```

```
     */
    int quality;

    /**
     * is this picture used as reference
     * The values for this are the same as the MpegEncContext.picture_structure
     * variable, that is 1->top field, 2->bottom field, 3->frame/both fields.
     * Set to 4 for delayed, non-reference frames.
     * - encoding: unused
     * - decoding: Set by libavcodec. (before get_buffer() call)).
     */
    int reference;

    /**QP表
     * QP table
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    int8_t *qscale_table;
    /**
     * QP store stride
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    int qstride;

    /**
     *
     */
    int qscale_type;

    /**跳过宏块表
     * mbskip_table[mb]>=1 if MB didn't change
     * stride= mb_width = (width+15)>>4
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    uint8_t *mbskip_table;

    /**运动矢量表
     * motion vector table
     * @code
     * example:
     * int mv_sample_log2= 4 - motion_subsample_log2;
     * int mb_width= (width+15)>>4;
     * int mv_stride= (mb_width << mv_sample_log2) + 1;
     * motion_val[direction][x + y*mv_stride][0->mv_x, 1->mv_y];
     * @endcode
     * - encoding: Set by user.
     * - decoding: Set by libavcodec.
     */
    int16_t (*motion_val[2])[2];

    /**宏块类型表
     * macroblock type table
     * mb_type_base + mb_width + 2
     * - encoding: Set by user.
     * - decoding: Set by libavcodec.
     */
    uint32_t *mb_type;

    /**DCT系数
     * DCT coefficients
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    short *dct_coeff;

    /**参考帧列表
     * motion reference frame index
     * the order in which these are stored can depend on the codec.
     * - encoding: Set by user.
     * - decoding: Set by libavcodec.
     */
    int8_t *ref_index[2];

    /**
     * for some private data of the user
     * - encoding: unused
     * - decoding: Set by user.
     */
    void *opaque;

    /**
     * error
     * - encoding: Set by libavcodec. if flags&CODEC_FLAG_PSNR.
     * - decoding: unused
     */
    uint64_t error[AV_NUM_DATA_POINTERS];

    /**
```

```
     * type of the buffer (to keep track of who has to deallocate data[*])
     * - encoding: Set by the one who allocates it.
     * - decoding: Set by the one who allocates it.
     * Note: User allocated (direct rendering) & internal buffers cannot coexist currently.
     */
    int type;

    /**
     * When decoding, this signals how much the picture must be delayed.
     * extra_delay = repeat_pict / (2*fps)
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    int repeat_pict;

    /**
     * The content of the picture is interlaced.
     * - encoding: Set by user.
     * - decoding: Set by libavcodec. (default 0)
     */
    int interlaced_frame;

    /**
     * If the content is interlaced, is top field displayed first.
     * - encoding: Set by user.
     * - decoding: Set by libavcodec.
     */
    int top_field_first;

    /**
     * Tell user application that palette has changed from previous frame.
     * - encoding: ??? (no palette-enabled encoder yet)
     * - decoding: Set by libavcodec. (default 0).
     */
    int palette_has_changed;

    /**
     * codec suggestion on buffer type if != 0
     * - encoding: unused
     * - decoding: Set by libavcodec. (before get_buffer() call)).
     */
    int buffer_hints;

    /**
     * Pan scan.
     * - encoding: Set by user.
     * - decoding: Set by libavcodec.
     */
    AVPanScan *pan_scan;

    /**
     * reordered opaque 64bit (generally an integer or a double precision float
     * PTS but can be anything).
     * The user sets AVCodecContext.reordered_opaque to represent the input at
     * that time,
     * the decoder reorders values as needed and sets AVFrame.reordered_opaque
     * to exactly one of the values provided by the user through AVCodecContext.reordered_opaque
     * @deprecated in favor of pkt_pts
     * - encoding: unused
     * - decoding: Read by user.
     */
    int64_t reordered_opaque;

    /**
     * hardware accelerator private data (FFmpeg-allocated)
     * - encoding: unused
     * - decoding: Set by libavcodec
     */
    void *hwaccel_picture_private;

    /**
     * the AVCodecContext which ff_thread_get_buffer() was last called on
     * - encoding: Set by libavcodec.
     * - decoding: Set by libavcodec.
     */
    struct AVCodecContext *owner;

    /**
     * used by multithreading to store frame-specific info
     * - encoding: Set by libavcodec.
     * - decoding: Set by libavcodec.
     */
    void *thread_opaque;

    /**
     * log2 of the size of the block which a single vector in motion_val represents:
     * (4->16x16, 3->8x8, 2-> 4x4, 1-> 2x2)
     * - encoding: unused
     * - decoding: Set by libavcodec.
     */
    uint8_t motion_subsample_log2;
```

```
330.
331.     /**（音频）采样率
332.      * Sample rate of the audio data.
333.      *
334.      * - encoding: unused
335.      * - decoding: read by user
336.      */
337.     int sample_rate;
338.
339.     /**
340.      * Channel layout of the audio data.
341.      *
342.      * - encoding: unused
343.      * - decoding: read by user.
344.      */
345.     uint64_t channel_layout;
346.
347.     /**
348.      * frame timestamp estimated using various heuristics, in stream time base
349.      * Code outside libavcodec should access this field using:
350.      * av_frame_get_best_effort_timestamp(frame)
351.      * - encoding: unused
352.      * - decoding: set by libavcodec, read by user.
353.      */
354.     int64_t best_effort_timestamp;
355.
356.     /**
357.      * reordered pos from the last AVPacket that has been input into the decoder
358.      * Code outside libavcodec should access this field using:
359.      * av_frame_get_pkt_pos(frame)
360.      * - encoding: unused
361.      * - decoding: Read by user.
362.      */
363.     int64_t pkt_pos;
364.
365.     /**
366.      * duration of the corresponding packet, expressed in
367.      * AVStream->time_base units, 0 if unknown.
368.      * Code outside libavcodec should access this field using:
369.      * av_frame_get_pkt_duration(frame)
370.      * - encoding: unused
371.      * - decoding: Read by user.
372.      */
373.     int64_t pkt_duration;
374.
375.     /**
376.      * metadata.
377.      * Code outside libavcodec should access this field using:
378.      * av_frame_get_metadata(frame)
379.      * - encoding: Set by user.
380.      * - decoding: Set by libavcodec.
381.      */
382.     AVDictionary *metadata;
383.
384.     /**
385.      * decode error flags of the frame, set to a combination of
386.      * FF_DECODE_ERROR_xxx flags if the decoder produced a frame, but there
387.      * were errors during the decoding.
388.      * Code outside libavcodec should access this field using:
389.      * av_frame_get_decode_error_flags(frame)
390.      * - encoding: unused
391.      * - decoding: set by libavcodec, read by user.
392.      */
393.     int decode_error_flags;
394. #define FF_DECODE_ERROR_INVALID_BITSTREAM   1
395. #define FF_DECODE_ERROR_MISSING_REFERENCE   2
396.
397.     /**
398.      * number of audio channels, only used for audio.
399.      * Code outside libavcodec should access this field using:
400.      * av_frame_get_channels(frame)
401.      * - encoding: unused
402.      * - decoding: Read by user.
403.      */
404.     int64_t channels;
405. } AVFrame;
```

AVFrame结构体一般用于存储原始数据（即非压缩数据，例如对视频来说是YUV，RGB，对音频来说是PCM），此外还包含了一些相关的信息。比如说，解码的时候存储了宏块类型表，QP表，运动矢量表等数据。编码的时候也存储了相关的数据。因此在使用FFMPEG进行码流分析的时候，AVFrame是一个很重要的结构体。

下面看几个主要变量的作用（在这里考虑解码的情况）：

uint8_t *data[AV_NUM_DATA_POINTERS]：解码后原始数据（对视频来说是YUV，RGB，对音频来说是PCM）

int linesize[AV_NUM_DATA_POINTERS]：data中“一行”数据的大小。注意：未必等于图像的宽，一般大于图像的宽。

int width, height：视频帧宽和高（1920x1080,1280x720...）

int nb_samples：音频的一个AVFrame中可能包含多个音频帧，在此标记包含了几个

int format：解码后原始数据类型（YUV420，YUV422，RGB24...）

int key_frame：是否是关键帧

enum AVPictureType pict_type：帧类型（I,B,P...）

AVRational sample_aspect_ratio：宽高比（16:9，4:3...）

int64_t pts：显示时间戳

int coded_picture_number：编码帧序号

int display_picture_number：显示帧序号

int8_t *qscale_table：QP表

uint8_t *mbskip_table：跳过宏块表

int16_t (*motion_val[2])[2]：运动矢量表

uint32_t *mb_type：宏块类型表

short *dct_coeff：DCT系数，这个没有提取过

int8_t *ref_index[2]：运动估计参考帧列表（貌似H.264这种比较新的标准才会涉及到多参考帧）

int interlaced_frame：是否是隔行扫描

uint8_t motion_subsample_log2：一个宏块中的运动矢量采样个数，取log的

其他的变量不再一一列举，源代码中都有详细的说明。在这里重点分析一下几个需要一定的理解的变量：

1.data[]

对于packed格式的数据（例如RGB24），会存到data[0]里面。

对于planar格式的数据（例如YUV420P），则会分开成data[0]，data[1]，data[2]...（YUV420P中data[0]存Y，data[1]存U，data[2]存V）

具体参见：FFMPEG 实现 YUV，RGB各种图像原始数据之间的转换（swscale）

2.pict_type

包含以下类型：

```cpp
enum AVPictureType {
    AV_PICTURE_TYPE_NONE = 0, ///< Undefined
    AV_PICTURE_TYPE_I,     ///< Intra
    AV_PICTURE_TYPE_P,     ///< Predicted
    AV_PICTURE_TYPE_B,     ///< Bi-dir predicted
    AV_PICTURE_TYPE_S,     ///< S(GMC)-VOP MPEG4
    AV_PICTURE_TYPE_SI,    ///< Switching Intra
    AV_PICTURE_TYPE_SP,    ///< Switching Predicted
    AV_PICTURE_TYPE_BI,    ///< BI type
};
```

3.sample_aspect_ratio

宽高比是一个分数，FFMPEG中用AVRational表达分数：

```cpp
/**
 * rational number numerator/denominator
 */
typedef struct AVRational{
    int num; ///< numerator
    int den; ///< denominator
} AVRational;
```

4.qscale_table

QP表指向一块内存，里面存储的是每个宏块的QP值。宏块的标号是从左往右，一行一行的来的。每个宏块对应1个QP。

qscale_table[0]就是第1行第1列宏块的QP值；qscale_table[1]就是第1行第2列宏块的QP值；qscale_table[2]就是第1行第3列宏块的QP值。以此类推...

宏块的个数用下式计算：

注：宏块大小是16x16的。

每行宏块数：

```cpp
int mb_stride = pCodecCtx->width/16+1
```

宏块的总数：

```cpp
int mb_sum = ((pCodecCtx->height+15)>>4)*(pCodecCtx->width/16+1)
```

5.motion_subsample_log2

1个运动矢量所能代表的画面大小（用宽或者高表示，单位是像素），注意，这里取了log2。

代码注释中给出以下数据：

4->16x16, 3->8x8, 2-> 4x4, 1-> 2x2

即1个运动矢量代表16x16的画面的时候，该值取4；1个运动矢量代表8x8的画面的时候，该值取3...以此类推

6.motion_val

运动矢量表存储了一帧视频中的所有运动矢量。

该值的存储方式比较特别：

```cpp
int16_t (*motion_val[2])[2];
```

为了弄清楚该值究竟是怎么存的，花了我好一阵子功夫...

注释中给了一段代码：

```cpp
int mv_sample_log2= 4 - motion_subsample_log2;
int mb_width= (width+15)>>4;
int mv_stride= (mb_width << mv_sample_log2) + 1;
motion_val[direction][x + y*mv_stride][0->mv_x, 1->mv_y];
```

大概知道了该数据的结构：

1.首先分为两个列表L0和L1

2.每个列表（L0或L1）存储了一系列的MV（每个MV对应一个画面，大小由 **motion_subsample_log2** 决定）

3.每个MV分为横坐标和纵坐标（x,y）

注意，在FFMPEG中MV和MB在存储的结构上是没有什么关联的，第1个MV是屏幕上左上角画面的MV（画面的大小取决于 **motion_subsample_log2**），第2个MV是屏幕上第1行第2列的画面的MV，以此类推。因此在一个宏块（16x16）的运动矢量很有可能如下图所示（line代表一行运动矢量的个数）：

```cpp
//例如8x8划分的运动矢量与宏块的关系：
                //-------------------------
                //|          |            |
                //|mv[x]     |mv[x+1]     |
                //-------------------------
                //|          |            |
                //|mv[x+line]|mv[x+line+1]|
                //-------------------------
```

7.mb_type

宏块类型表存储了一帧视频中的所有宏块的类型。其存储方式和QP表差不多。只不过其是uint32类型的，而QP表是uint8类型的。每个宏块对应一个宏块类型变量。

宏块类型如下定义所示：

```cpp
//The following defines may change, don't expect compatibility if you use them.
#define MB_TYPE_INTRA4x4   0x0001
#define MB_TYPE_INTRA16x16 0x0002 //FIXME H.264-specific
#define MB_TYPE_INTRA_PCM  0x0004 //FIXME H.264-specific
#define MB_TYPE_16x16      0x0008
#define MB_TYPE_16x8       0x0010
#define MB_TYPE_8x16       0x0020
#define MB_TYPE_8x8        0x0040
#define MB_TYPE_INTERLACED 0x0080
#define MB_TYPE_DIRECT2    0x0100 //FIXME
#define MB_TYPE_ACPRED     0x0200
#define MB_TYPE_GMC        0x0400
#define MB_TYPE_SKIP       0x0800
#define MB_TYPE_P0L0       0x1000
#define MB_TYPE_P1L0       0x2000
#define MB_TYPE_P0L1       0x4000
#define MB_TYPE_P1L1       0x8000
#define MB_TYPE_L0         (MB_TYPE_P0L0 | MB_TYPE_P1L0)
#define MB_TYPE_L1         (MB_TYPE_P0L1 | MB_TYPE_P1L1)
#define MB_TYPE_L0L1       (MB_TYPE_L0   | MB_TYPE_L1)
#define MB_TYPE_QUANT      0x00010000
#define MB_TYPE_CBP        0x00020000
//Note bits 24-31 are reserved for codec specific use (h264 ref0, mpeg1 0mv, ...)
```

一个宏块如果包含上述定义中的一种或两种类型，则其对应的宏块变量的对应位会被置1。
注：一个宏块可以包含好几种类型，但是有些类型是不能重复包含的，比如说一个宏块不可能既是16x16又是8x8。

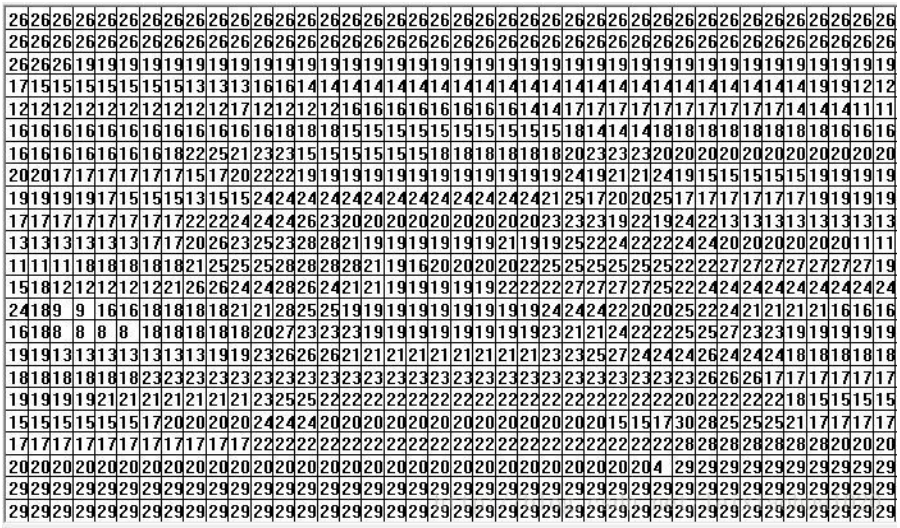
8.ref_index

运动估计参考帧列表存储了一帧视频中所有宏块的参考帧索引。这个列表其实在比较早的压缩编码标准中是没有什么用的。只有像H.264这样的编码标准才有多参考帧的概念。但是这个字段目前我还没有研究透。只是知道每个宏块包含有4个该值，该值反映的是参考帧的索引。以后有机会再进行细研究吧。

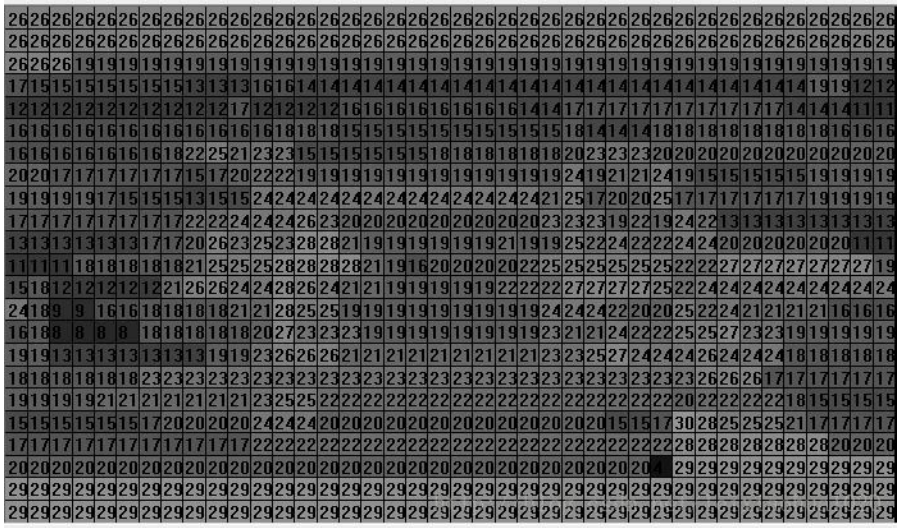
在这里展示一下自己做的码流分析软件的运行结果。将上文介绍的几个列表图像化显示了出来（在这里是使用MFC的绘图函数画出来的）

视频帧：

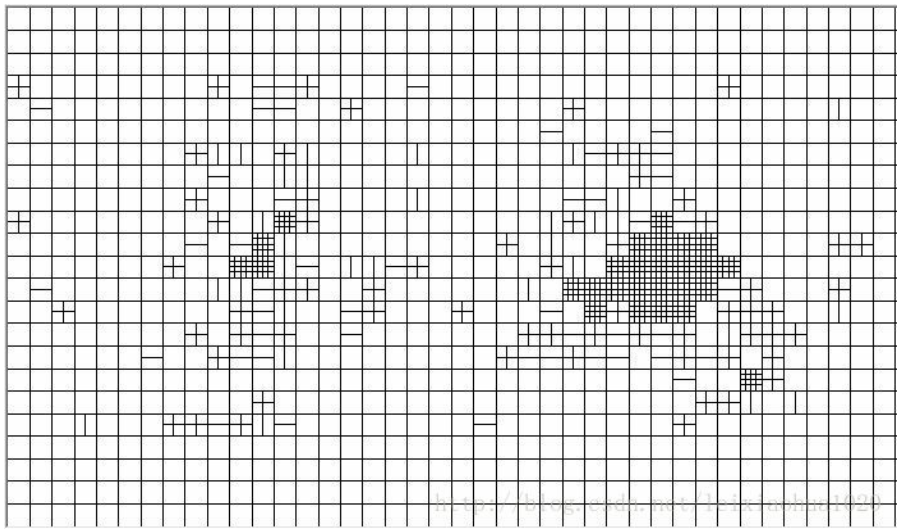
QP参数提取的结果：



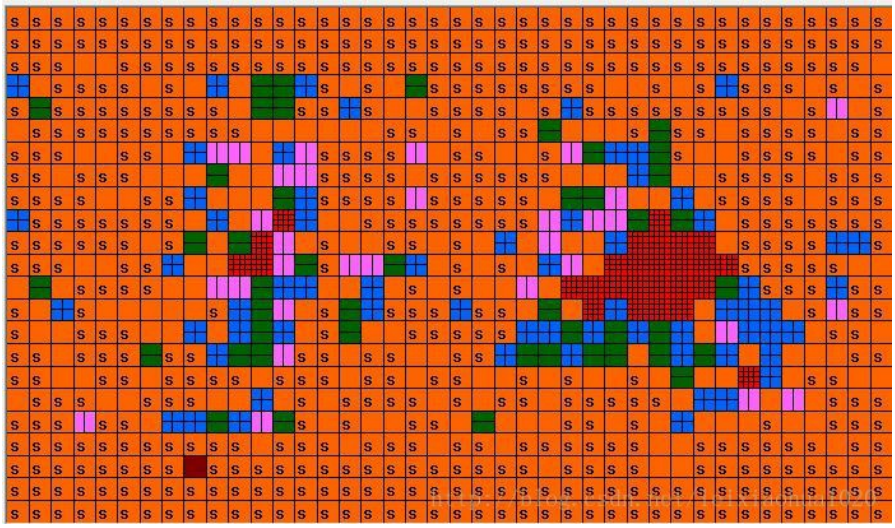
美化过的（加上了颜色）：



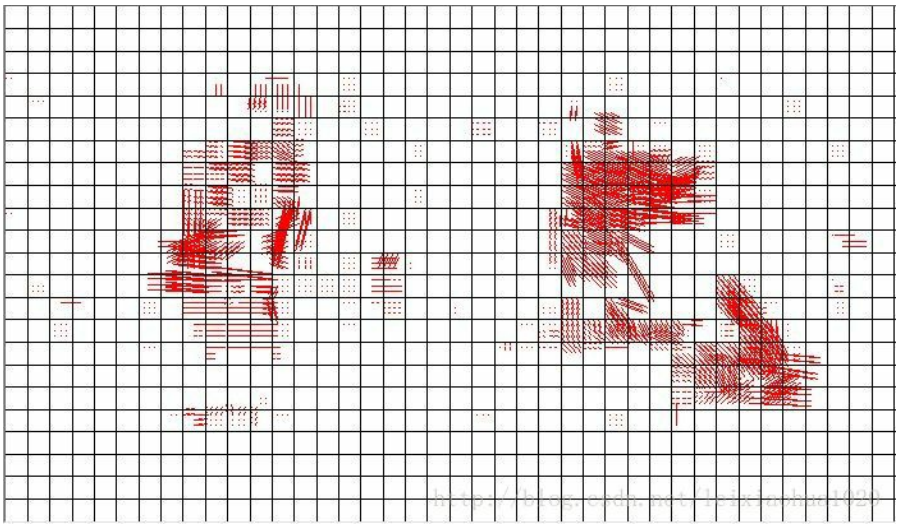
宏块类型参数提取的结果：



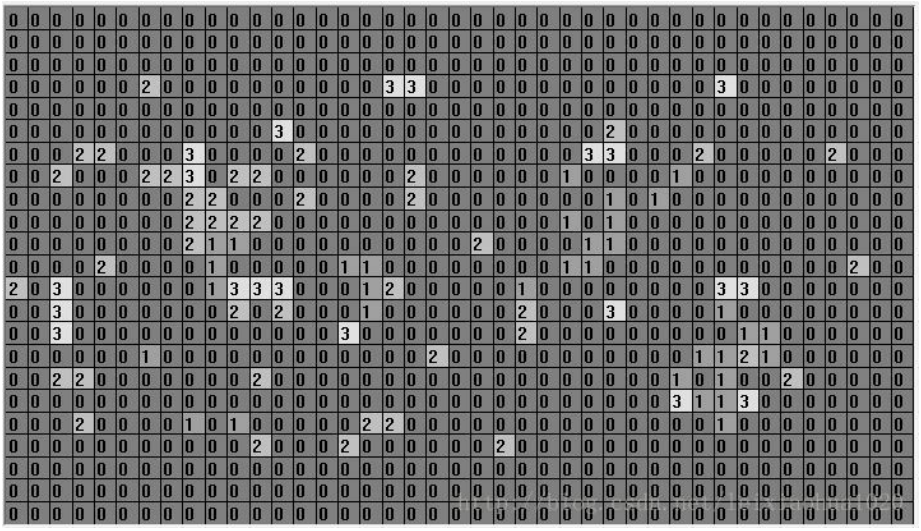
美化过的（加上了颜色，更清晰一些，s代表skip宏块）：



运动矢量参数提取的结果（在这里是List0）：



运动估计参考帧参数提取的结果：



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