

原 FFMPEG结构体分析：AVFrame

2013年11月06日 21:15:05 阅读数：90227

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]
1.  /*
2.   *雷霄骅
3.   *leixiaohua1020@126.com
4.   *中国传媒大学/数字电视技术
5.   */
6.  /**
7.   * Audio Video Frame.
8.   * New fields can be added to the end of AVFRAME with minor version
9.   * bumps. Similarly fields that are marked as to be only accessed by
10.  * av_opt_ptr() can be reordered. This allows 2 forks to add fields
11.  * without breaking compatibility with each other.
12.  * Removal, reordering and changes in the remaining cases require
13.  * a major version bump.
14.  * sizeof(AVFrame) must not be used outside libavcodec.
15.  */
16.  typedef struct AVFrame {
17.  #define AV_NUM_DATA_POINTERS 8
18.    /**图像数据
19.     * pointer to the picture/channel planes.
20.     * This might be different from the first allocated byte
21.     * - encoding: Set by user
22.     * - decoding: set by AVCodecContext.get_buffer()
23.     */
24.    uint8_t *data[AV_NUM_DATA_POINTERS];
25.
26.    /**
27.     * Size, in bytes, of the data for each picture/channel plane.
28.     *
29.     * For audio, only linesize[0] may be set. For planar audio, each channel
30.     * plane must be the same size.
31.     *
32.     * - encoding: Set by user
33.     * - decoding: set by AVCodecContext.get_buffer()
34.     */
35.    int linesize[AV_NUM_DATA_POINTERS];
36.
37.    /**
38.     * pointers to the data planes/channels.
39.     *
40.     * For video, this should simply point to data[].
41.     *
42.     * For planar audio, each channel has a separate data pointer, and
43.     * linesize[0] contains the size of each channel buffer.
44.     * For packed audio, there is just one data pointer, and linesize[0]
45.     * contains the total size of the buffer for all channels.
46.     *
47.     * Note: Both data and extended_data will always be set by get_buffer(),
48.     * but for planar audio with more channels that can fit in data,
49.     * extended_data must be used by the decoder in order to access all
50.     * channels.
51.     *
52.     * encoding: unused
53.     * decoding: set by AVCodecContext.get_buffer()
54.     */
55.    uint8_t **extended_data;
56. }
```

```

57.  /**宽高
58.   * width and height of the video frame
59.   * - encoding: unused
60.   * - decoding: Read by user.
61.   */
62.  int width, height;
63.
64.  /**
65.   * number of audio samples (per channel) described by this frame
66.   * - encoding: Set by user
67.   * - decoding: Set by libavcodec
68.   */
69.  int nb_samples;
70.
71.  /**
72.   * format of the frame, -1 if unknown or unset
73.   * Values correspond to enum AVPixelFormat for video frames,
74.   * enum AVSampleFormat for audio)
75.   * - encoding: unused
76.   * - decoding: Read by user.
77.   */
78.  int format;
79.
80.  /**是否是关键帧
81.   * 1 -> keyframe, 0-> not
82.   * - encoding: Set by libavcodec.
83.   * - decoding: Set by libavcodec.
84.   */
85.  int key_frame;
86.
87.  /**帧类型 (I,B,P)
88.   * Picture type of the frame, see ?_TYPE below.
89.   * - encoding: Set by libavcodec. for coded_picture (and set by user for input).
90.   * - decoding: Set by libavcodec.
91.   */
92.  enum AVPictureType pict_type;
93.
94.  /**
95.   * pointer to the first allocated byte of the picture. Can be used in get_buffer/release_buffer.
96.   * This isn't used by libavcodec unless the default get/release_buffer() is used.
97.   * - encoding:
98.   * - decoding:
99.   */
100.  uint8_t *base[AV_NUM_DATA_POINTERS];
101.
102.  /**
103.   * sample aspect ratio for the video frame, 0/1 if unknown/unspecified
104.   * - encoding: unused
105.   * - decoding: Read by user.
106.   */
107.  AVRational sample_aspect_ratio;
108.
109.  /**
110.   * presentation timestamp in time_base units (time when frame should be shown to user)
111.   * If AV_NOPTS_VALUE then frame_rate = 1/time_base will be assumed.
112.   * - encoding: MUST be set by user.
113.   * - decoding: Set by libavcodec.
114.   */
115.  int64_t pts;
116.
117.  /**
118.   * reordered pts from the last AVPacket that has been input into the decoder
119.   * - encoding: unused
120.   * - decoding: Read by user.
121.   */
122.  int64_t pkt_pts;
123.
124.  /**
125.   * dts from the last AVPacket that has been input into the decoder
126.   * - encoding: unused
127.   * - decoding: Read by user.
128.   */
129.  int64_t pkt_dts;
130.
131.  /**
132.   * picture number in bitstream order
133.   * - encoding: set by
134.   * - decoding: Set by libavcodec.
135.   */
136.  int coded_picture_number;
137.  /**
138.   * picture number in display order
139.   * - encoding: set by
140.   * - decoding: Set by libavcodec.
141.   */
142.  int display_picture_number;
143.
144.  /**
145.   * quality (between 1 (good) and FF_LAMBDA_MAX (bad))
146.   * - encoding: Set by libavcodec. for coded_picture (and set by user for input).
147.   * - decoding: Set by libavcodec.

```

```

148.     */
149.     int quality;
150.
151.     /**
152.      * is this picture used as reference
153.      * The values for this are the same as the MpegEncContext.picture_structure
154.      * variable, that is 1->top field, 2->bottom field, 3->frame/both fields.
155.      * Set to 4 for delayed, non-reference frames.
156.      * - encoding: unused
157.      * - decoding: Set by libavcodec. (before get_buffer() call)).
158.      */
159.     int reference;
160.
161.     /**QP表
162.      * QP table
163.      * - encoding: unused
164.      * - decoding: Set by libavcodec.
165.      */
166.     int8_t *qscale_table;
167.     /**
168.      * QP store stride
169.      * - encoding: unused
170.      * - decoding: Set by libavcodec.
171.      */
172.     int qstride;
173.
174.     /**
175.      *
176.      */
177.     int qscale_type;
178.
179.     /**跳过宏块表
180.      * mbskip_table[mb]>=1 if MB didn't change
181.      * stride= mb_width = (width+15)>>4
182.      * - encoding: unused
183.      * - decoding: Set by libavcodec.
184.      */
185.     uint8_t *mbskip_table;
186.
187.     /**运动向量表
188.      * motion vector table
189.      * @code
190.      * example:
191.      * int mv_sample_log2= 4 - motion_subsample_log2;
192.      * int mb_width= (width+15)>>4;
193.      * int mv_stride= (mb_width << mv_sample_log2) + 1;
194.      * motion_val[direction][x + y*mv_stride][0->mv_x, 1->mv_y];
195.      * @endcode
196.      * - encoding: Set by user.
197.      * - decoding: Set by libavcodec.
198.      */
199.     int16_t (*motion_val[2])[2];
200.
201.     /**宏块类型表
202.      * macroblock type table
203.      * mb_type_base + mb_width + 2
204.      * - encoding: Set by user.
205.      * - decoding: Set by libavcodec.
206.      */
207.     uint32_t *mb_type;
208.
209.     /**DCT系数
210.      * DCT coefficients
211.      * - encoding: unused
212.      * - decoding: Set by libavcodec.
213.      */
214.     short *dct_coeff;
215.
216.     /**参考帧列表
217.      * motion reference frame index
218.      * the order in which these are stored can depend on the codec.
219.      * - encoding: Set by user.
220.      * - decoding: Set by libavcodec.
221.      */
222.     int8_t *ref_index[2];
223.
224.     /**
225.      * for some private data of the user
226.      * - encoding: unused
227.      * - decoding: Set by user.
228.      */
229.     void *opaque;
230.
231.     /**
232.      * error
233.      * - encoding: Set by libavcodec. if flags&CODEC_FLAG_PSNR.
234.      * - decoding: unused
235.      */
236.     uint64_t error[AV_NUM_DATA_POINTERS];
237.
238.     /**

```

```

239.     * type of the buffer (to keep track of who has to deallocate data[*])
240.     * - encoding: Set by the one who allocates it.
241.     * - decoding: Set by the one who allocates it.
242.     * Note: User allocated (direct rendering) & internal buffers cannot coexist currently.
243.     */
244.     int type;
245.
246.     /**
247.     * When decoding, this signals how much the picture must be delayed.
248.     * extra_delay = repeat_pict / (2*fps)
249.     * - encoding: unused
250.     * - decoding: Set by libavcodec.
251.     */
252.     int repeat_pict;
253.
254.     /**
255.     * The content of the picture is interlaced.
256.     * - encoding: Set by user.
257.     * - decoding: Set by libavcodec. (default 0)
258.     */
259.     int interlaced_frame;
260.
261.     /**
262.     * If the content is interlaced, is top field displayed first.
263.     * - encoding: Set by user.
264.     * - decoding: Set by libavcodec.
265.     */
266.     int top_field_first;
267.
268.     /**
269.     * Tell user application that palette has changed from previous frame.
270.     * - encoding: ??? (no palette-enabled encoder yet)
271.     * - decoding: Set by libavcodec. (default 0).
272.     */
273.     int palette_has_changed;
274.
275.     /**
276.     * codec suggestion on buffer type if != 0
277.     * - encoding: unused
278.     * - decoding: Set by libavcodec. (before get_buffer() call)).
279.     */
280.     int buffer_hints;
281.
282.     /**
283.     * Pan scan.
284.     * - encoding: Set by user.
285.     * - decoding: Set by libavcodec.
286.     */
287.     AVPanScan *pan_scan;
288.
289.     /**
290.     * reordered opaque 64bit (generally an integer or a double precision float
291.     * PTS but can be anything).
292.     * The user sets AVCodecContext.reordered_opaque to represent the input at
293.     * that time,
294.     * the decoder reorders values as needed and sets AVFrame.reordered_opaque
295.     * to exactly one of the values provided by the user through AVCodecContext.reordered_opaque
296.     * @deprecated in favor of pkt_pts
297.     * - encoding: unused
298.     * - decoding: Read by user.
299.     */
300.     int64_t reordered_opaque;
301.
302.     /**
303.     * hardware accelerator private data (FFmpeg-allocated)
304.     * - encoding: unused
305.     * - decoding: Set by libavcodec
306.     */
307.     void *hwaccel_picture_private;
308.
309.     /**
310.     * the AVCodecContext which ff_thread_get_buffer() was last called on
311.     * - encoding: Set by libavcodec.
312.     * - decoding: Set by libavcodec.
313.     */
314.     struct AVCodecContext *owner;
315.
316.     /**
317.     * used by multithreading to store frame-specific info
318.     * - encoding: Set by libavcodec.
319.     * - decoding: Set by libavcodec.
320.     */
321.     void *thread_opaque;
322.
323.     /**
324.     * log2 of the size of the block which a single vector in motion_val represents:
325.     * (4->16x16, 3->8x8, 2-> 4x4, 1-> 2x2)
326.     * - encoding: unused
327.     * - decoding: Set by libavcodec.
328.     */
329.     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]
1. enum AVPictureType {
2.     AV_PICTURE_TYPE_NONE = 0, ///< Undefined
3.     AV_PICTURE_TYPE_I,      ///< Intra
4.     AV_PICTURE_TYPE_P,      ///< Predicted
5.     AV_PICTURE_TYPE_B,      ///< Bi-dir predicted
6.     AV_PICTURE_TYPE_S,      ///< S(GMC)-VOP MPEG4
7.     AV_PICTURE_TYPE_SI,     ///< Switching Intra
8.     AV_PICTURE_TYPE_SP,     ///< Switching Predicted
9.     AV_PICTURE_TYPE_BI,     ///< BI type
10. };
```

3.sample_aspect_ratio

宽高比是一个分数，FFMPEG中用AVRational表达分数：

```
[cpp]
1. /**
2.  * rational number numerator/denominator
3.  */
4. typedef struct AVRational{
5.     int num; ///< numerator
6.     int den; ///< denominator
7. } 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：

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

宏块的总数：

```
1. 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：

```
1. 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：

```
1. int mv_sample_log2= 4 - motion_subsample_log2;
2. int mb_width= (width+15)>>4;
3. int mv_stride= (mb_width << mv_sample_log2) + 1;
4. 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）：

```
1. //例如8x8划分的运动矢量与宏块的关系：
2. //-----
3. //|           |           |
4. //|mv[x]      |mv[x+1]    |
5. //|           |           |
6. //|           |           |
7. //|mv[x+line] |mv[x+line+1]|
8. //|           |           |
   //-----
```

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：

```

1. //The following defines may change, don't expect compatibility if you use them.
2. #define MB_TYPE_INTRA4x4 0x0001
3. #define MB_TYPE_INTRA16x16 0x0002 //FIXME H.264-specific
4. #define MB_TYPE_INTRA_PCM 0x0004 //FIXME H.264-specific
5. #define MB_TYPE_16x16 0x0008
6. #define MB_TYPE_16x8 0x0010
7. #define MB_TYPE_8x16 0x0020
8. #define MB_TYPE_8x8 0x0040
9. #define MB_TYPE_INTERLACED 0x0080
10. #define MB_TYPE_DIRECT2 0x0100 //FIXME
11. #define MB_TYPE_ACPRED 0x0200
12. #define MB_TYPE_GMC 0x0400
13. #define MB_TYPE_SKIP 0x0800
14. #define MB_TYPE_P0L0 0x1000
15. #define MB_TYPE_P1L0 0x2000
16. #define MB_TYPE_P0L1 0x4000
17. #define MB_TYPE_P1L1 0x8000
18. #define MB_TYPE_L0 (MB_TYPE_P0L0 | MB_TYPE_P1L0)
19. #define MB_TYPE_L1 (MB_TYPE_P0L1 | MB_TYPE_P1L1)
20. #define MB_TYPE_L0L1 (MB_TYPE_L0 | MB_TYPE_L1)
21. #define MB_TYPE_QUANT 0x00010000
22. #define MB_TYPE_CBP 0x00020000
23. //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：



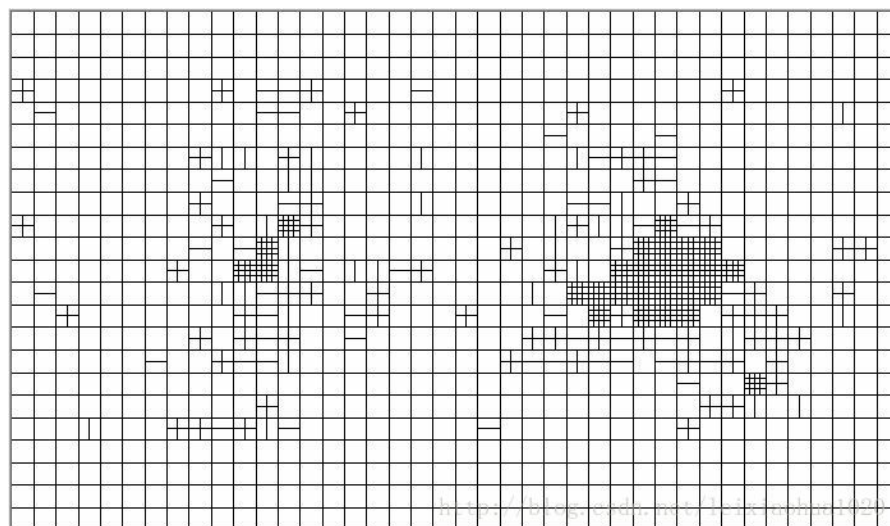
QP参数提取的结果：

[illegible]

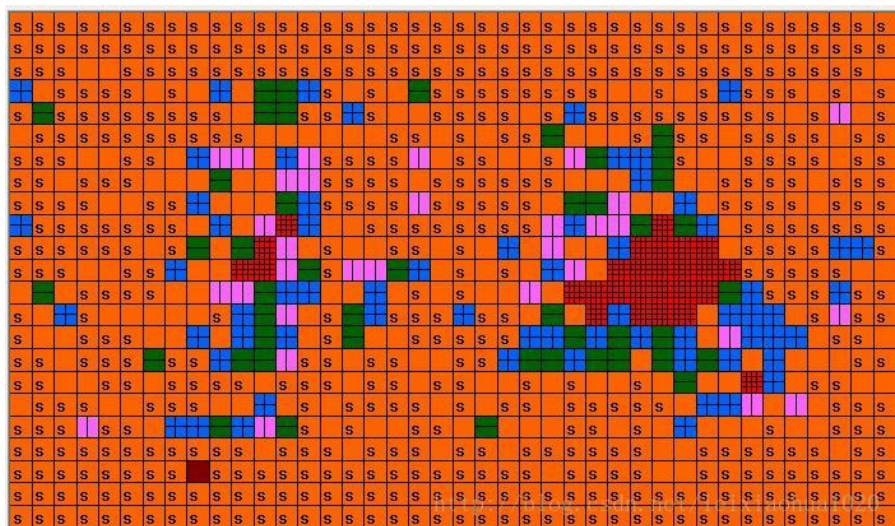
美化过的（加上了颜色）：

[illegible]

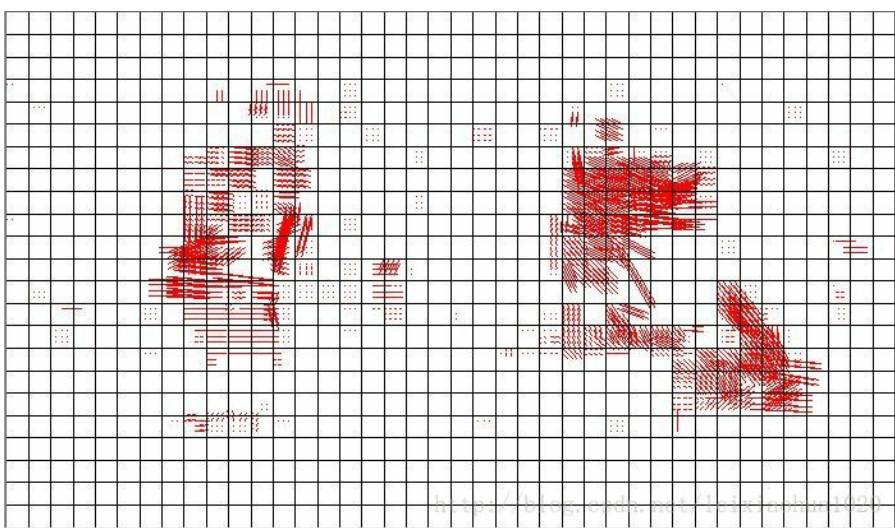
宏块类型参数提取的结果：



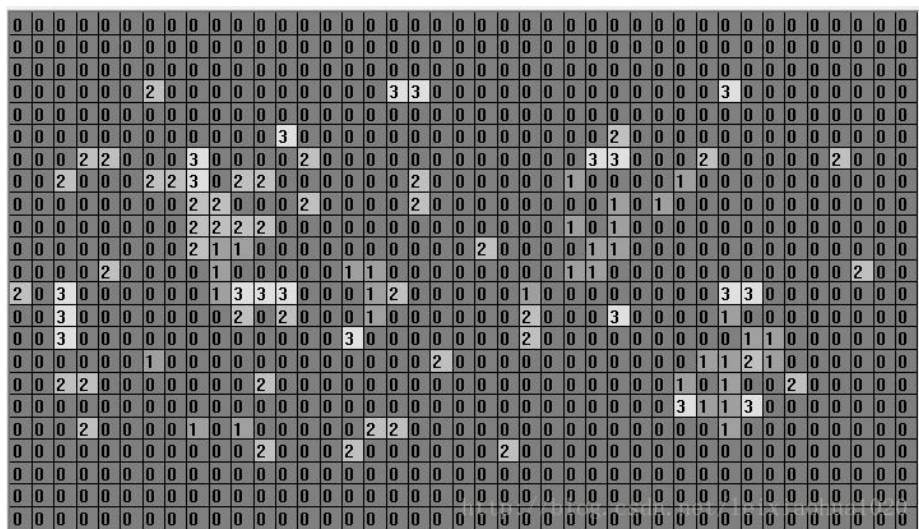
美化过的（加上了颜色，更清晰一些，s代表skip宏块）：



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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