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2D/3D AudioVisual Content Analysis & Description (Invited Overview Paper)

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Abstract—In this paper, we propose a way of using the Audio-Visual Description Profile (AVDP) of the MPEG-7 standard for 2D or stereo video and multichannel audio content description. Our aim is to provide means of using AVDP in such a way, that 3D video and audio content can be correctly and consistently described. Since AVDP semantics do not include ways for dealing with 3D audiovisual content, a new semantic framework within AVDP is proposed and examples of using AVDP to describe the results of analysis algorithms on stereo video and multichannel audio content are presented.

Index Terms—AudioVisual Description Profile (AVDP), MPEG-7, stereo video, semantic content description

I. INTRODUCTION

Recorded, broadcasted and webcasted data increase exponentially with time and thus a considerable amount of research is geared towards finding ways to analyse, describe and annotate video content in an efficient and automatic manner. Automatic analysis of video and audio includes various tasks e.g., shot/scene boundary detection, person detection/tracking/recognition, facial expression recognition, music/speech segmentation, speaker diarization and music genre/mood characterization. The relevant algorithms are used in various applications, such as semantic description of video content for archival, indexing and retrieval, implementation of better audiovisual editing tools, intelligent content manipulation, etc.

A rather new trend in multimedia is the use of stereoscopic video. Many of the recent film productions have their 3D versions [1]. Analysis of stereoscopic video has the advantage of benefiting from the additional available information, namely depth/disparity, which can boost the performance of analysis algorithms, such as the ones mentioned above. In addition, analysis of stereoscopic video can derive information that cannot be inferred from single-view video, such as 3D object position. Finally, the particularities of 3D video call for analysis algorithms that can characterize 3D video quality or its conformance to the rules of 3D cinematography [2].

For handling audiovisual content annotation and description, MPEG-7 standardizes a set of Descriptors (Ds), Description Schemes (DSs), a description definition language (DDL) and

a description encoding. A considerable amount of effort has been invested over the last years to improve MPEG-7 ability to deal with semantic content description. Nevertheless, 3D audiovisual content description has not yet been investigated in the MPEG-7 context. Although some description and description schemes have been proposed to model 3D information, they are only explicit descriptors for geometrical information and not for 3D video content.

The AudioVisual Description Profile (AVDP) has been recently adopted as a new profile of the MPEG-7 standard [3], [4]. This profile consists of a subset of the original MPEG-7 standard and aims at describing the results of most of the known audiovisual analysis tasks (e.g., shot detection, face detection/tracking), in a normative manner. AVDP was designed to benefit both broadcasters and the digital media industry in order to create a normative layer between media content production and consumption. In this paper, we propose to store 3D video and multichannel audio content (e.g., 3DTV content) semantic analysis results to an XML file compatible to the specifications of the AVDP. Our aim is to show that AVDP can be used, by properly utilizing its descriptors and description schemes, for describing and storing the results of 3D (but also 2D) audiovisual content analysis.

II. THE USE OF THE AUDIOVISUAL DESCRIPTION PROFILE FOR 3D CONTENT DESCRIPTION

The AudioVisual Description Profile (AVDP) provides a normative way to store high and low level information, extracted from the analysis of video and/or audio content. We have selected a subset of the decomposition types (namely TemporalDecomposition (TD), MediaSourceDecomposition (MSD), SpatioTemporalDecomposition (STD), SpatialDecomposition (SD)) available in the AVDP, in order to create various segment types (AudioVisualSegment (AVS), VideoSegment (VS), AudioSegment (AS), StillRegion (SR), MovingRegion (MR)) for representing the output of various analysis algorithms. In our approach, a content entity is used as the root of the description for a specific channel. Such a channel can be a color or disparity channel (left/right) of a stereo video segment or the audio content description, which

unlike video is stored in a single content entity despite the fact that multichannel audio is present. All the relevant information of a channel obtained by various media analysis algorithms is stored within the content entity representing the corresponding channel by employing the above mentioned decomposition and segment types. Information that does not refer to a specific video channel (e.g., left or right), but to the 3D video as a whole, is stored to a reference channel, namely left channel. In the following sections, we will describe a number of 3D video and audio content analysis algorithms and the way their results can be stored using AVDP. Figure 1 illustrates the proposed AVDP usage for 3D content description. It should be noted here that most of the proposed description approaches apply also to classic (2D) video content.

Fig. 1. Schematization of AVDP usage for 3D content description.

A. Scene/Shot Boundary Description

resulting in a temporal decomposition of a multimedia content into different scenes/shots [5], [6]. In terms of AVDP, a TemporalDecomposition of an AudioVisualSegment describing the entire channel of a 3D video content is generated. Each resulting AudioVisualSegment represents a scene/shot. Moreover, with the same approach we can handle the case of shot transitions, such as fade-in, fade-out, dissolve etc. In all the cases, the type of the segment (e.g., scene, shot, transition of a certain type) is stored using the StructuralUnit element within the AudioVisualSegment. Additionally, semantic characterizations of scenes/shots, such as comfortable for 3D viewing, wide, close-up or popup, is provided using the How element of the StructuralAnnotation type. In the following partial XML example, a shot with its time and shot type information (long shot) is described:

Terms used for the characterization of shots or scenes are defined in a Classification Scheme (CS). A part of this CS is provided below:

B. Key Frame and Key Video Segment Description

C. Event Detection

An event is a semantically important concept having a certain duration in the audiovisual stream, such as a dialogue among people or a car accident. For describing events occurring within a shot, we use the TemporalDecomposition type of the VideoSegment, representing the visual information of the shot. The criteria attribute is set to “events”, to create a series of VideoSegments, each corresponding to a single event. The specific type of an event is stored within the StructuralUnit element of VideoSegment. An example of a dialogue occurring in the time interval [10, 50] is shown below:

```
<TemporalDecomposition
  criteria="DecompositionCS#events">
  <VideoSegment id="Event_13">
    <StructuralUnit href="StructuralUnitCS#event.dialogue"/>
    <MediaTime>
      <MediaRelIncrTimePoint>10</MediaRelIncrTimePoint>
      <MediaIncrDuration>41</MediaIncrDuration>
    </MediaTime>
  </VideoSegment>
</TemporalDecomposition>
```

The various event types can be organized within an appropriate CS, as shown in the following example:

```
<Term termID="event">
  <Name xml:lang="en">event</Name>
  <Definition xml:lang="en">Video segment is annotated as
    an event segment</Definition>
  <Term termID="event.dialogue">
    <Name xml:lang="en">dialogue event</Name>
    <Definition xml:lang="en">Video segment is annotated as
      a dialogue event</Definition>
  </Term>
  <Term termID="event.crash">
    <Name xml:lang="en">crash event</Name>
    <Definition xml:lang="en">Video segment is annotated as
      a crash event</Definition>
  </Term>
</Term>
```

D. Semantic 3D Video Quality Descriptions

3D video quality is highly related to the depth perception and the visual comfort while watching such a video [2], [8]. Semantic qualitative descriptions of 3D quality are more intuitive than quantitative descriptions and thus are preferred. Such descriptions can be at the shot level, pre frame or refer to a segment of the video. Shot level 3D quality semantic descriptions include information related to e.g., depth continuity, syncness, or depth stress. Annotation of the VideoSegment representing a shot is done by assigning the 3D quality semantic terms via the How element of StructuralAnnotation. Frame level 3D quality descriptions include information related to e.g., colorimetric or contrast mismatch, and are stored using the same approach as above within the StillRegion that corresponds to the frame. The semantic terms are defined in a respective Classification Scheme file. 3D video quality defects such as stereoscopic window violations, bent window effects or depth jump cuts refer to a segment of the video and the corresponding characterizations are stored as events (see Section III-C). An example of 3D quality description at shot level is given below:

```
<VideoSegment id="vis_shot_0">
  <StructuralUnit href="StructuralUnitCS#vis_shot"/>
  <TextAnnotation>
```

```
<StructuredAnnotation>
  <How href="SemanticFeat3dCS#DisparityMap.high"/>
  <How href="SemanticFeat3dCS#DepthBudget.low"/>
</StructuredAnnotation>
</TextAnnotation>
<MediaTime>
  <MediaRelIncrTimePoint>0</MediaRelIncrTimePoint>
  <MediaIncrDuration>149</MediaIncrDuration>
</MediaTime>
</VideoSegment>
```

An example of a CS containing term definitions for shot and frame level 3D quality description is shown below:

```
<Term termID="DisparityMap">
  <Name xml:lang="en">Disparity map</Name>
  <Definition xml:lang="en">Horizontal or vertical
    disparity map</Definition>
  <Term termID="DisparityMap.low">
    <Name xml:lang="en">Low</Name>
    <Definition xml:lang="en">Low depth range of the
      disparity map</Definition>
  </Term>
  <Term termID="DisparityMap.medium">
    <Name xml:lang="en">Medium</Name>
    <Definition xml:lang="en">Medium depth range of the
      disparity map</Definition>
  </Term>
  <Term termID="DisparityMap.high">
    <Name xml:lang="en">High</Name>
    <Definition xml:lang="en">High depth range of the
      disparity map</Definition>
  </Term>
</Term>
```

E. Person/Face/Object Description in Stereo Video

The description of an object (e.g., a person, a face, a car, a ball) is performed after object/person detection and tracking that provide the location of an object over time. In the case of humans, additional information can be included, such as depicted activity or facial expression. Semantic characterizations of object/person position and motion can also be stored.

In more detail, object detection is the process of finding the location of a predefined object (e.g. a face, a car, a ball etc) in a per-frame basis [9]. Since the object detector usually detects a specific object or a specific object category, this information can be used to semantically annotate the detected object type. To store the location of the detected object(s), usually in terms of a bounding box, as well as other relevant information, a StillRegion type is used for each detected object, where the specific type (e.g., face, car) is stored, within the StructuralUnit element, while the SpatialLocator type is used to hold the coordinates of the bounding box.

Object/person tracking produces the trajectory of a predefined object (e.g., a face) in a sequence of video frames. Usually, object tracking is initialized by an object detector and performed in a video segment in a frame-by-frame basis [10]. The spatial position of the tracked object (usually in the form of a bounding box) over time forms the object trajectory. The type e.g. face or ball, and the coordinates of the bounding boxes of a trajectory are stored within the StructuralUnit and SpatioTemporalLocator elements of a MovingRegion, respectively.

The resulting StillRegions (detection) and MovingRegions (tracking) are stored within the VideoSegment representing the visual information of the corresponding shot. As can be seen in Figure 1, we use a MediaSourceDecomposition type,

to decompose this VideoSegment into a list of StillRegion elements, where each of them represents an entire frame of the video segment. Subsequently, we decompose each frame into further StillRegions representing detected objects through a SpatialDecomposition type. Similarly, we use a SpatioTemporalDecomposition type to decompose the VideoSegment, representing the visual information of the corresponding shot, into a list of MovingRegion elements where each of them represents an object trajectory. In 3D video content, correspondences between StillRegions (e.g. bounding boxes) or MovingRegions (e.g. trajectories), that correspond to the same depiction of the object in two channels, e.g. between the right and left video channel, should be established. To denote such a correspondence, we use the Relation type in order to connect two Segment types, namely StillRegions and MovingRegions across channels.

After object/person detection and tracking, various video analysis algorithms may be used for extracting semantic descriptions for these entities, e.g., information regarding person identity, facial expression or activity and/or object motion. More specifically, human activity recognition can be used to recognize specific predefined human activities, such as run or walk on a person trajectory. Such information can be stored using the WhatAction element of the StructuredAnnotation of the respective StillRegion or MovingRegion. Moreover, facial expression recognition labels, such as happiness, anger, fear etc., can be stored in the WhatAction element. The value “affect” is used within the StructuredAnnotation of the respective StillRegion or MovingRegion, whereas the How element holds the recognized expression.

By using geometrical reasoning algorithms, one can also annotate 3D or 2D video content with information related to the geometric or motion properties of objects or object ensembles [11]. Such properties may refer to the geometrical position of an actor or object in the 3D world, the size of an actor/object, the location of a displayed object with respect to the screen or the stereoscopic comfort zone, the direction of object motion etc. In the case of stereo video, object position and motion characterization in the depth domain can be obtained. Such geometric descriptions are stored using appropriate elements of the StructuralAnnotation type of StillRegions and MovingRegions. Specifically, the Where, WhatObject and How elements are used to store labels related to the position (e.g., “left”, “near”, “in front of screen”), size and movement (e.g., “left”, “forward”) of an object, respectively.

Image regions depicting faces (facial images) can be clustered into clusters of actors through a facial image clustering algorithm [12]. For storing the results of face/object clustering (i.e., labels such as Actor_1, Actor_2,...), we update appropriately the Who/WhatObject element, respectively, in the structured annotation of each involved segment type (StillRegion and MovingRegion).

It should be noted that in all above cases, the href attribute of the various elements (namely Who, WhatObject, How, Where) of StructuralAnnotation is updated by utilizing

appropriate terms from corresponding Classification Schemes. A Classification Scheme example which contains terms for characterizing the position of an object is presented below:

```
<Term termID="in_front_of_screen">
  <Name xml:lang="en">in front of screen</Name>
  <Definition xml:lang="en">One or many still/moving regions
    are in front of the screen plane</Definition>
</Term>
<Term termID="in_comfort_zone">
  <Name xml:lang="en">in comfort zone</Name>
  <Definition xml:lang="en">The position of one or many
    still/moving regions is in comfort zone</Definition>
</Term>
```

Relations between faces and real persons may be obtained through manual annotation or through a face recognition algorithm. For example, a face, that is automatically detected and is given an abstract face term (e.g., Actor_1) after face clustering, may be annotated as depicting a certain real person (e.g., Jack Smith). Hence, relations between abstract face terms and real names may be obtained. Each such relation is represented by a StructuredAnnotation which contains two ‘Who’ elements: the first ‘Who’ element holds the corresponding abstract face term and the second a term from a Classification Scheme containing real names of actors. The resulting StructuredAnnotations are stored in the top level structure for content description, namely the AudioVisual.

In the following XML example, a face trajectory, where the depicted person is happy and running, as well as the relation between Face_1 and Jack Smith is described:

```
<Description xsi:type="ContentEntityType">
  <MultimediaContent xsi:type="AudioVisualType">
    <AudioVisual id="CHANNEL_left" mediaTimeUnit="PT1N25F">
      <StructuralUnit href="StructuralUnitCS#channel.left_view"/>
      <TextAnnotation><StructuredAnnotation>
        <Who href="PersonCS#Jack_Smith"/>
        <Who href="FaceCS#1"/>
      </StructuredAnnotation></TextAnnotation>
      <MediaTime>
        <MediaRelIncrTimePoint>0</MediaRelIncrTimePoint>
        <MediaIncrDuration>1000</MediaIncrDuration>
      </MediaTime>
      <TemporalDecomposition
        criteria="DecompositionCS#shots" id="ShotSet_1">
        ...
        <SpatioTemporalDecomposition
          criteria="DecompositionCS#humans">
          <MovingRegion id="MovingObject_97">
            <StructuralUnit
              href="StructuralUnitCS#face.trajectory"/>
            <TextAnnotation>
              <StructuredAnnotation>
                <WhatAction href="ActionCS#run"/>
              </StructuredAnnotation>
              <StructuredAnnotation>
                <WhatAction href="ActionCS#affect"/>
                <How href="AffectCS#happiness"/>
              </StructuredAnnotation>
              <StructuredAnnotation>
                <Who href="FaceCS#1"/>
              </StructuredAnnotation>
            </TextAnnotation>
            <Relation strength="1.0" target="MovingObject_121"/>
          <SpatioTemporalLocator>
            <ParameterTrajectory motionModel="still">
              <MediaTime>
                <MediaRelIncrTimePoint>188</MediaRelIncrTimePoint>
                <MediaIncrDuration>1</MediaIncrDuration>
              </MediaTime><InitialRegion><Polygon>
                <Coords mpeg7:dim="2 4">38 33 0 -33 19 0 35 0
                </Coords></Polygon></InitialRegion>
            </ParameterTrajectory>
          </SpatioTemporalLocator>
```

```

        </MovingRegion>
    </SpatioTemporalDecomposition>
    ...
</TemporalDecomposition>
</AudioVisual>
</MultimediaContent>
</Description>

```

F. Soccer Analysis in Stereo Video

3D Soccer analysis extracts diverse semantic information, such as camera view class, players positions and identities and interesting highlights [13], [14]. More specifically, a shot of a soccer match can be assigned to a camera view class, which basically depends on the camera zoom level: overview, medium view, out-of-field or close-up. Such class label is stored as a How element within the StructuralAnnotation of the VideoSegment representing the visual information of the respective shot. Soccer highlights such as corners, goals, etc can also be annotated, using the same approach used for annotating events (see Section III-C). Finally, players can be detected and tracked for the duration of their appearance. Similar to other subjects (e.g., actors in a movie), a MovingRegion is used to represent a player's trajectory, while its name is stored in the Who element of the StructuralAnnotation type. In the following example, a shot of a soccer match is characterized as overview shot and a corner is stored as an event:

```

<VideoSegment id="vis.shot_1">
  <StructuralUnit href="StructuralUnitCS#vis.shot"/>
  <TextAnnotation><StructuredAnnotation>
    <How><Name>Overview</Name></How>
  </StructuredAnnotation></TextAnnotation>
  <MediaTime>
    <MediaRelIncrTimePoint>149</MediaRelIncrTimePoint>
    <MediaIncrDuration>91</MediaIncrDuration>
  </MediaTime>
  <TemporalDecomposition
    criteria="DecompositionCS#events">
    <VideoSegment id="EVID_0">
      <StructuralUnit href="event.corner"/>
      <MediaTime>
        <MediaRelIncrTimePoint>250</MediaRelIncrTimePoint>
        <MediaIncrDuration>49</MediaIncrDuration>
      </MediaTime>
    </VideoSegment>
    </TemporalDecomposition>
  </VideoSegment>

```

IV. MULTICHANNEL AUDIO DESCRIPTION

Description of audio sources and events in 5.1 or 7.1 multichannel audio can also be performed by using the MPEG-7 AVDP profile. A TemporalDecomposition of an AudioSegment describing the audio information of a 3D video content is applied to generate AudioSegments. Each resulting AudioSegment represents one or more audio sources. These sources can be an event (goal in a football match, applause before or at the end of a concert) an object (speeding car, flying helicopter), music (along with characterizations for music genre, music mood), speech, or a speaker (in the sense of speaker diarization/clustering).

A. Audio event description

An audio event is stored in an AudioSegment type, specifying its temporal location and duration. Audio events can overlap. For the description of an audio event, a StructuredAnnotation type using WhatObject, WhatObject/Who and

WhatObject/How elements is used. Those elements use IDs that point to a hierarchical Classification Scheme describing all audio sources (see Section IV-C). Due to the existence of multichannel audio, the analysis algorithms are also able to provide information about the audio source position in the form of FreeTextAnnotation, using two optional terms "source_azimuth" and "source_width". The following XML example describes the source position location for a audio source (car) at azimuth=15° and width=20°:

```

<AudioSegment id="source_4">
  <StructuralUnit href="StructuralUnitCS#4"/>
  <TextAnnotation>
    <FreeTextAnnotation>source_azimuth=15, source_width=20
  </FreeTextAnnotation>
  <StructuredAnnotation>
    <WhatObject href="Audio3DTVSCS#car"/>
  </StructuredAnnotation>
  </TextAnnotation>
  <MediaTime>
    <MediaRelIncrTimePoint>220</MediaRelIncrTimePoint>
    <MediaIncrDuration>300</MediaIncrDuration>
  </MediaTime>
</AudioSegment>

```

B. Music and speech segmentation

The temporal segmentation of the audio stream in speech and music segments is an important task in audio analysis. The music segments can be further classified into music genre and music mood classes. The speech segments can also be organized into speaker clusters. The speech and music segments are stored in an AudioSegment type and described using a StructuredAnnotation type. For speech, the WhatObject/Who elements are used to indicate the presence of speech and the active speaker (corresponding to Speaker_1, Speaker2,...). For music, the WhatObject/How elements are used to store the presence of music and the music genre and music mood information. In the following example, the fact that Speaker_2 is heard is described.

```

<AudioSegment id="source_3">
  <StructuralUnit href="StructuralUnitCS#4"/>
  <TextAnnotation>
    <StructuredAnnotation>
      <WhatObject href="Audio3DCS#Speech"/>
      <Who href="Audio3DCS#Speaker_2"/>
    </StructuredAnnotation>
  </TextAnnotation>
  <MediaTime>
    <MediaRelIncrTimePoint>200</MediaRelIncrTimePoint>
    <MediaIncrDuration>100</MediaIncrDuration>
  </MediaTime>
</AudioSegment>

```

C. Classification Scheme

A hierarchical scheme is used so as to be able to specify the general type of the audio source (e.g., music or speech) using WhatObject terms and then to specify more detailed information for speech (Who term for speaker identity e.g., Speaker_1, Speaker_2), music (How term for music genre e.g., classical or pop and music mood e.g., happy) and object (WhatObject term for object e.g., car), as depicted in the example CS below.

```

<Term termID="1">
  <Name xml:lang="en">Music</Name>
  <Definition xml:lang="en">Define an audio segment within
    an AV media where music is present</Definition>

```

```

<Term termID="1.1">
  <Name xml:lang="en">MusicGenre</Name>
  <Definition xml:lang="en">Define the music genre of an
    audio segment</Definition>
  <Term termID="1.1.1">
    <Name xml:lang="en">classical</Name>
    <Definition xml:lang="en">Music belong to the Classical
      music genre</Definition>
  </Term>
</Term>
<Term termID="1.2">
  <Name xml:lang="en">MusicMood</Name>
  <Definition xml:lang="en">Define the mood of a music
    segment</Definition>
  <Term termID="1.2.1">
    <Name xml:lang="en">happy</Name>
    <Definition xml:lang="en">Music mood: happy</Definition>
  </Term>
</Term>
<Term termID="3">
  <Name xml:lang="en">AudioEvent</Name>
  <Definition xml:lang="en">Define an audio segment within an
    AV media where an audio-event is present</Definition>
  <Term termID="3.1">
    <Name xml:lang="en">Goal</Name>
    <Definition xml:lang="en">Segment where the audio is
      produced by a goal event</Definition>
  </Term>
</Term>

```

V. DESCRIPTION OF MULTIMODAL ANALYSIS RESULTS

Multimodal person clustering is defined as the analysis task in which facial appearances in video, resulting from face clustering, and speakers audio segments, resulting from speaker diarization, are jointly processed in order to improve the results in one or both modalities and also establish relations between facial appearances and speakers that correspond to the same person. Each such relation is represented by two StructuredAnnotations which contain two Who elements: the first StructuredAnnotation holds the corresponding abstract face term generated by the face clustering and a term from a Classification Scheme, the second one holds the corresponding abstract speaker term from the speaker diarization and the same term from the above mentioned CS. This CS contains a sufficient number of abstract terms which are used to link the same person across audio and video. Because these relations refer to the entire movie, the resulting StructuredAnnotations are stored in the top level structure for content description, namely the AudioVisual. The following example illustrates the relation between Face_1 and Speaker_3:

```

<Description xsi:type="ContentEntityType">
  <MultimediaContent xsi:type="AudioVisualType">
    <AudioVisual id="CHANNEL" mediaTimeUnit="PT1N25F">
      <StructuralUnit href="StructuralUnitCS#channel.left_view"/>
      <TextAnnotation>
        <StructuredAnnotation>
          <Who href="FaceCS#1"/>
          <Who href="AbstractPersonCS#1"/>
        </StructuredAnnotation>
        <StructuredAnnotation>
          <Who href="SpeakerCS#3"/>
          <Who href="AbstractPersonCS#1"/>
        </StructuredAnnotation>
      </TextAnnotation>
    </AudioVisual>
  </MultimediaContent>
</Description>

```

VI. CONCLUSIONS

In this paper we have presented a new way of using the AVDP profile of the MPEG-7 standard for 3D video content

description that can accommodate multiple audio and video (left/right, color/disparity) channels. We have detailed how we can store the results of several audiovisual analysis algorithms within such a context and how specific 3D metadata can be incorporated in the framework. The proposed framework can be used for storing the analysis results in a 3DTV media asset management (MAM) system. Such a system can then be queried and return the video e.g., where actor X appears in the comfort zone in a 3D context. The proposed XML description can be easily extended to support multiview video coming from multiple cameras. Parts of the description can also be used for 2D content description.

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