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Mobile Cinema - Canonical Processes for Video Adaptation

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ABSTRACT
Nowadays, users not only want to watch digital videos on a PC but also use mobile devices to play back multimedia content. *Video adaptation* algorithms enable the visualization of recorded videos on mobile devices. Based on our *Mobile Business* system, we have developed a video adaptation application called *Mobile Cinema* which considers several characteristic features of mobile devices like screen resolution, bit rate or color depth of a display. The functionality of this system is high and it would be much easier to understand the system if the analysis and the design of the algorithms and the communication interfaces are based on predefined processes which we call *canonical processes for media production*. The definition of these processes would also make the comparison of two video adaptation applications or the exchange of modules between different systems much easier. In this paper, we describe the functionality and requirements of our existing video adaptation application and map them to the canonical processes for media production.

Categories and Subject Descriptors
H.1 [Models and Principles]: General; I.4.3 [Image processing and computer vision]: Enhancement; I.2.10 [Artificial Intelligence]: Vision and Scene Understanding

General Terms
Design, Standardization

Keywords
Canonical processes, video process modeling, video adaptation.

1. INTRODUCTION
The technological development of small mobile computers has increased significantly over the last few years. Mobile phones, digital cameras and PDAs are replaced by devices combining and integrating different functionalities (mail client, web browser, organizer, phone, photo camera, games). Significant differences between the characteristic features of mobile devices exist. Relevant in our context are the screen resolution, the color depth of the display, the memory, CPU, network interfaces, and the software running on the device.

If an application for mobile devices is developed it is not only necessary to consider the characteristic features of one device. Otherwise, an application would run well on a few devices, but the acceptance of the application would be low if another device is used. In spite of the large number of mobile devices, the number of device-independent applications is very limited.

In 2005, we have started the ambitious *Mobile Business* project at the University of Mannheim. Its aim is to develop a software infrastructure to support the development of applications for mobile devices [13]. Seven departments from the faculties of computer science and business administration and more than 25 scientists cooperate on this goal. We focus on context-aware applications: applications automatically considering the context of a user, such as time, location, and user preferences.

We completed the *Mobile Business* infrastructure prototype, and several applications have been developed based on this infrastructure. One major goal was to develop a generic infrastructure, so that the applications can run on different devices. It is especially relevant that suitable techniques are available to visualize multimedia content. E. g., a video cannot be visualized on a mobile device if the spatial resolution or the bandwidth are insufficient. Our task in the *Mobile Business* project was to develop an application enabling the *automatic adaptation of multimedia content*. Our video adaptation application called *Mobile Cinema* considers the screen resolution, network capacities, the color depth of the display and different video formats. User preferences can be defined as well to modify the adaptation process.

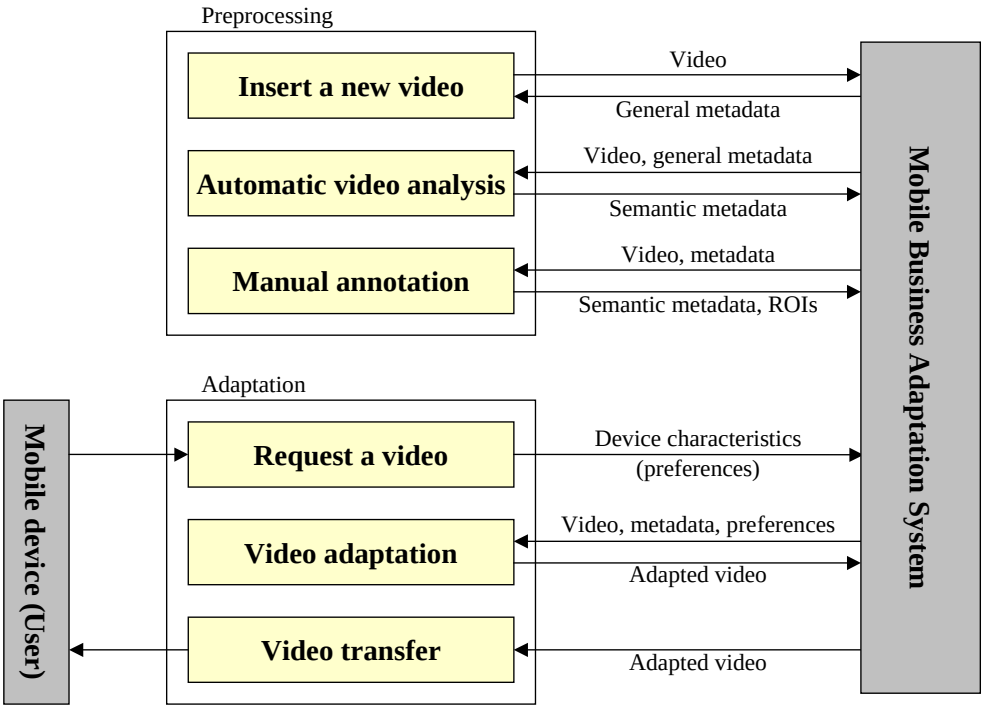

Figure 1: Overview of the video adaptation processes

The application we have developed supports the adaptation of images and videos so far. Currently, we are working on techniques for the adaptation of entire Web pages. In the following, we will focus on our video adaptation application. Several adaptation techniques have been proposed which usually focus on re-coding aspects [1, 16, 17]. Our application does not only re-code a video to change the format like the spatial resolution or bit rate. Rather, our goal is to *preserve the semantic content* of a video. For example, visual content is lost if the image resolution is scaled down and text becomes unreadable.

The functionality of the video adaptation application is quite complex: A considerable amount of data is exchanged with its environment, and the communication between the *Mobile Business* system and the applications is intensive. Standardization of inter-process communication and the interfaces makes the understanding of the video adaptation processes much easier. E. g., if a component of our *Mobile Cinema* application should be used in another application, the definition of the input, output and functionality in a standardized way would be very helpful. Many standards like MPEG-7 [5] or MPEG-21 [6] exist which facilitate the exchange of metadata for multimedia content. On the other hand, the description of multimedia processes is not standardized yet.

The aim of our work is to identify and specify the interfaces and processes of our existing video adaptation application. To archive this goal, we will map the existing functionality to predefined processes. The description of the processes is based on "canonical processes of media production" which were proposed by the Dagstuhl working group "Multimedia for Human Communication" [3, 4]. We will analyze our application, identify required functionalities, and map them to the predefined processes canonical to media production.

The remainder of this paper is organized as follows: Section 2 gives an overview of the processes of our video adaptation system and analyses their functionalities. Section 3 describes the mapping of these processes to canonical processes in media production. We discuss the identified processes in detail in Section 4 and conclude the paper in Section 5.

2. PROCESSES IN THE CONTEXT OF VIDEO ADAPTATION

We have developed several applications based on our *Mobile Business* system, including a gastronomy guide and a bargain hunter. In the following, we will focus on another application in which video adaptation is most important. The idea of the *Mobile Cinema* application is to enable a good visualization of feature films on different kinds of mobile devices. We focus on the visualization of people, foreground objects and actions, which seem to be most relevant in most movies.

The *Mobile Cinema* application can be divided in two major parts. In the preprocessing step, a new video is added into the *Mobile Business* system. To enable a good adaptation the semantic content of a movie must be considered. Therefore, each video is analyzed automatically, and the detected semantic features are stored. We have developed an editor enabling users to validate the auto-

matically generated metadata and to insert additional information about the video.

The adaptation is done in a second step. A user sends a request for a specific video from his mobile device to the *Mobile Business* system. The adaptation is started if the parameters of the requested video and the features of the mobile device do not match. The adapted video is sent to the mobile device and additionally stored in the *Mobile Business* system.

We have identified six processes in the Mobile Cinema application relevant to video adaptation:

1. Inserting a new video
2. Automatic video analysis
3. Manual annotation
4. Requesting a video
5. Video adaptation
6. Video transfer

Figure 1 gives an overview of these processes. In the following, we will discuss each step in detail.

2.1 Insert a new video

In a first step, a new movie is added to the system. We assume that recorded videos are available in a digitized format. Capturing or editing of raw video footage is not supported in the Mobile Business system. Most movies are stored as MPEG-1 or MPEG-2 videos, although other video formats are supported as well.

General information is computed for each video. A unique identifier is generated which is used to reference the video. Parameters of the video like its length, the image resolution, the frame rate, the bit rate and the video format are detected and stored in the *Mobile Business* system.

A user does not only insert a new video into the system but also specifies some general information that cannot be derived from the video automatically, such as the title, copyright or date of creation. This information is associated with the video identifier and stored in the Mobile Business system.

2.2 Automatic video analysis

The analysis process is automatically started for each new video. The idea is to get the information required for the semantic adaptation in a later step. In a first step, the adaptation application identifies shot boundaries. In a second step, semantic content such as faces, foreground objects and superimposed text is identified for each shot separately. The automatically detected features are stored in the *Mobile Business* system.

We give two examples of automatically detected semantic features in the following. *Persons* are very important in most feature films. Close-up views of the faces of the main actors are especially relevant in feature films, whereas historical documentaries often feature sports persons or politicians. We have implemented a face recognition algorithm based on neural networks [15]. The algorithm reliably detects about 90 percent of the frontal faces in a video; non-face areas (i.e. false hits) are rare.

Moving objects deliver additional semantic information. The number of moving objects in a video is also an important indicator. A film of a car race or a tennis match repeatedly shows moving cars or tennis players. Our object recognition algorithm consists of two components: a segmentation module and a classification module [2]. In a first step, a background image is computed, and foreground objects are extracted by means of temporal filtering. Object segmentation is then performed by evaluating differences between the current frame and the computed background.

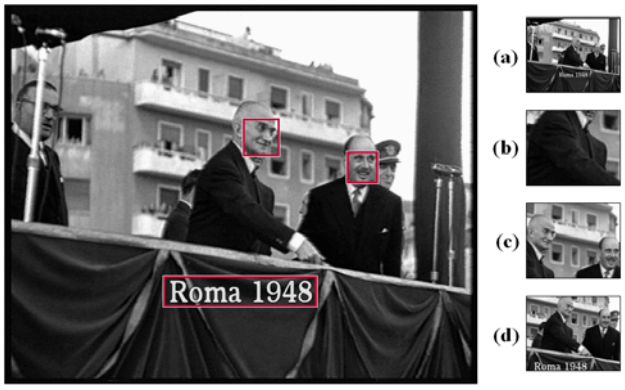

Figure 2: Adaptation of the resolution by scaling (a) and cropping of image borders (b). The quality of the adapted image is much better if two (c) or three (d) semantic features are considered.

The classification module analyzes the segmented object masks in a second step. For each mask, an efficient shape-based representation is calculated based on a curvature scale space (CSS) diagram [8]. The CSS technique is based on the idea of curve evolution; it provides a multi-scale representation of the curvature zero crossings of a closed planar contour. The matching process compares these contour descriptors to pre-calculated object descriptions. The position, size and name of the classified objects are stored in the *Mobile Business* system.

2.3 Manual annotation

The automatic analysis fails in many cases. An application for editing the metadata manually was thus developed to modify the automatically calculated data. The editor offers a comfortable way to validate, change or delete information about the movie.

To insert new data, a rectangular region can be marked in a frame, and textual annotations can be added. The region describes a single semantic feature or highlights an interesting part of the frame. For each region, a value characterizing its relevance can be defined. The validation of the automatically calculated metadata guarantees, that the adaptation application uses correct information.

2.4 Request a video

When all metadata has been calculated it is possible to access a video from a mobile device. A user sends a request for a video to the *Mobile Business* system. The requirements of the user's device are transferred in this step. Our system handles the adaptation of the screen resolution [7, 10], the frame rate, the bit rate, the color depth of the display [9, 11] and different video formats. Additionally, user preferences can be defined and transmitted to the system, e. g., the adaptation algorithm focuses on people if the user increases the priority to include faces or persons.

The system validates whether the requirements are compatible with the stored videos. The adaptation engine is started if this is

not the case. The video identifier, the characteristic features of the mobile device and the user preferences define the parameters for the adaptation.

2.5 Video adaptation

As an example, we will only describe the adaptation of the screen resolution. The adaptation application must guarantee that even in case of very small displays the relevant content can be recognized. The adaptation is done by *scaling* and/or *selecting* a rectangular region (cropping of borders). We use a combination of scaling and cropping and add an artificial camera zoom or camera motion to highlight relevant content. The example in Figure 2 (c) and (d) illustrates that a combination of scaling and cropping leads to good results. Three semantic features have been detected, as indicated in Figure 2.

Often, scaling or cropping alone do not produce acceptable results (see Figure 2 (a) and (b)). The *Mobile Cinema* application applies four heuristics to select a relevant region:

- Regions with semantic content should be clearly visible in the adapted video. A region should not be part of the adapted video if the semantic content is no longer recognizable due to its limited size.
- Regions without interesting content should not be part of the adapted video. Dark borders (e. g., black stripes on the top and bottom of wide-screen movies) or large monochrome regions adjoining an image border (e. g., sky) are typical candidates of irrelevant regions.
- A selected region is scaled to the appropriate screen resolution. The aspect ratio of the selected region should be identical to the aspect ratio of the adapted video.
- Different regions can be selected within a shot to visualize more details. A continuous modification generates an artificial camera motion; a sudden shift of the camera produces a hard cut.

To apply these rules, the video adaptation application aggregates the semantic features and regions of interest in each shot. A rating of the semantic features is necessary to identify the region to select. We assume a proportional coherence between the size of a semantic feature in the adapted video and the visual information in the frame. A *minimal perceptible size* is defined for each feature: The content is no longer recognizable if the size of a feature drops below this value. Additionally, we define an upper size for each feature (*maximal reasonable size*). For instance, if the font size of a text is readable, an enlargement of the characters does not provide additional information.

The output of the aggregation step is a rectangular region, which defines the visible area of the adapted video. The frames are clipped and scaled to the appropriate size and an adapted video is generated.

2.6 Video transfer

In the last step, the adapted video is sent to the *Mobile Business* system. The system stores the adapted video, defines a unique identifier, saves the parameters which have been used to create it, and handles the transfer of the adapted video to the mobile device. The Mobile Cinema application aggregates the video adaptation and video transfer in one process. The video is streamed to the server and forwarded to the mobile device. The combination of both processes makes an adaptation on the fly possible.

3. CANONICAL PROCESSES FOR VIDEO ADAPTATION

Several canonical processes are required to get a precise description of our *Mobile Cinema* application. Table 1 gives an overview of the mapping from adaptation processes and canonical processes. Some processes (e. g., *Query*) are relevant to describe the full functionality of the *Mobile Business* system, but are not relevant for the video adaptation application. These processes were left out.

3.1 Preprocessing a video

The canonical process *Annotate* is most important for the preprocessing. Some general information about the video is stored in the system, first. Part of this information is computed automatically, like the unique identifier or the length of the video (*computing annotator*). A person (*human annotator*) adds additional information, like the title or date of creation. The annotation describes the complete video, in contrast to the output of the video analysis step. The computed and manually added metadata is grouped (canonical *Package* process), and the unique identifier is used to reference the video.

The automatic video analysis process is another typical example for the process *Annotate*. The video and general information are already stored in the archive, and additional information is added by this process. Shots are specified by start and end time, and the type and length of a transition. Semantic features like faces, objects and text regions are identified for each shot. A data record stores the identifier of the video, a time code and information about the feature (description, location, size). The video and general annotations are used as input for this process. Again, the *Package* process is relevant to group the video and all annotations. The process *Premeditate* describes the decision process of the program developers.

Adding, deleting or changing metadata is done in the last preprocessing step. Regions of interest which visualize important content are specified in this step, too. A *human annotator* validates all data and guarantees correct information.

3.2 Video adaptation

Several canonical processes are relevant to describe the video adaptation. A major decision (process *Premeditate*) was already made by us when we decided which heuristics and metadata to use for the adaptation. The results of this step are annotations in the form of a design document for the *Mobile Cinema* application.

The two processes *Create Media Asset* and *Publish* are most important for the adaptation. The process *Create* is relevant because the *Mobile Cinema* application significantly modifies the original video and generates a new one. The newly created video is stored in the *Mobile Business* system and sent to the mobile device of a user. The *Mobile Cinema* application can be directly mapped to the process actor *Generation Program*, because a new video is created. On the other hand, the adaptation also describes a transformation of a video which can be better mapped by the process actor *Editing Program*. The adapted video (*Media Asset*) and the adaptation parameters (*Creation Metadata*) are the output of this process. We do not need a device or an operator/editor to create

the new content. These elements are replaced by the adaptation software.

On the other hand, not all aspects of the adaptation process can be described by the *Create* process. The adaptation is based on the specifications of a mobile device. Therefore, the adaptation can be characterized as a tool which helps to visualize a video. This functionality is best handled by the process *Publish*, which describes how to visualize a video for external use. The output of the *Publish* process are the adapted video (*Media Asset Selected for Publication*) and the parameters used for the adaptation. The *Publisher* in this process is the *Mobile Cinema* application.

Other processes are used during the adaptation, too. The process *Annotate* describes how to store the parameters which are used for the adaptation (e. g., device specifications, user preferences). The process *Package* groups the adapted videos and parameters. A user has a specific intention if he modifies the default parameters of the adaptation application, e. g., to make specific content easier to recognize. The process *Construct Message* describes the user interaction. The experience and the ideas of the author are used as input, and the selected parameters are the output of this step.

4. DISCUSSION

We had some discussions whether the process *Publish* or *Create Media Asset* is more suitable to describe the video adaptation. If we use the *Publish* process, we assume that the semantic content of the adapted and the original video is very similar. This is the case, if e. g. the left and right border of a widescreen cinema movie is cropped to fit to a normal TV screen. Only a small part of the image is removed and relevant semantic information is usually not lost. In this scenario, the adaptation is a typical *Publish* process that focuses on the refinement of the source video to enable a suitable visualization and makes it ready for presentation.

Additionally, we use the process *Create Media Asset* that describes the production of a *new* video. We usually loose relevant information about the semantic content if we adapt a high-resolution video to the limited screen size of a mobile device. We cannot guarantee that the automatic adaptation process does not completely change the basic message of the film because visual content is changed or lost due to the scaling and cropping of the video. E. g., it might not only be relevant to hear the speech of a person but also to watch the expression of his face or see a specific object he is speaking about. The meaning of a scene may be completely lost if relevant semantic content is not visualized.

The *Create Media Asset* process describes the video adaptation better, if we assume that a new video is generated. The application does not use raw footage, in contrast to the traditional production of films, but re-uses recorded and finished videos. New videos with possibly new content are generated automatically based on the recorded videos. The result is a semantically adapted video which is stored in the *Mobile Business* system. Not only the new video as such is relevant but also the information about the creation process. Although the adapted video and the adaptation parameters are stored, the new video is handled in a different way compared to the original video. A reference is available which links to the original video, and no semantic metadata is stored for the new video.

It depends on the adaptation scenario which of the processes (*Create* or *Publish*) fit better. The *Mobile Cinema* application should be applicable in both scenarios. Therefore, the processes *Create* and *Publish* are mandatory to describe it. The application merges both canonical processes into a complex process, which uses the original video, its metadata and the user preferences as input and creates a completely new or slightly changed video. Relevant information for the adaptation process is lost if only one canonical process is used.

The video adaptation application creates and uses a large amount of metadata. Therefore, the process *Annotate* is also relevant. Every process (insert video, analysis, manual annotation, and adaptation) generates new metadata to be stored in the archive and associated with the video. The annotation process handles the storage of the parameters for the generation of adapted videos. Most annotations are calculated automatically, and we assume that in the future the amount of automatically annotated metadata will increase further due to the fact, that the quality of automatic annotation systems improves over time [14].

We expect that canonical processes of media production will make the analysis, design and implementation of new algorithms easier. The transformation of a process to predefined canonical processes enables a better understanding of the communication between processes. It is not an easy task to compare complex multimedia systems which provide similar functionality. E. g., it would be interesting to compare the functionality of our *Mobile Cinema* application with other video adaptation systems like Video Retargeting [12], which applies very similar techniques but uses an optimization process to minimize the information loss in the adapted video. The comparison of the functionality of these applications and the identification of missing or additional features would be much easier if descriptions based on canonical processes are available.

Another interesting approach would be to merge two complex multimedia applications by exchanging selected modules and replacing or adding new functionality. Not only two video adaptation applications could be merged, but it would be also interesting to use semantic metadata in our *Mobile Cinema* application which is automatically generated for video summarization or video indexing purposes. Even new systems could be developed like a tool to create resolution adapted video summaries. This could be useful, if e. g. an overview of newscasts should be generated for mobile devices. Functionalities of both applications – the adaptation of the screen size and a reduction of the length of the video – are required. A combination of adaptation and summarization algorithms that use the same semantic metadata might lead to a good solution, and canonical processes might help to define the relevant processes much easier.

In the case of our *Mobile Cinema* application, the modification of recorded videos is of special interest. It is also important to store metadata about the semantic content of an adapted video. Otherwise, all semantic information which can be derived from the original video would be lost. The transfer of the semantic content of the original video to the adapted video is still an open issue because some information may be invalid due to the adaptation (e. g., due to cropping, a relevant person might be missing in the adapted video clip). Another challenge is the problem of lost updates: If the annotation of the original video is manually changed these changes should be transferred and merged with all other versions of the video.

To avoid this problem, we store the information about the semantic features only with the original video. To get information about the semantic content, we use a bidirectional link between the adapted video and the original. Only user preferences and the adaptation parameters are merged and stored for each adapted video.

5. CONCLUSION

We have presented the requirements and the functionality of our existing adaptation application which is based on our *Mobile Business* system. The metadata exchange for the *Mobile Cinema* application is high, and much information has to be stored. We have identified the most important processes and mapped them to the predefined canonical processes of media production. We are convinced that the development of multimedia applications would be much more efficient if standardized canonical processes were used on a regular basis.

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Canonical process	**Processes of the *Mobile Cinema* application**
Annotate	**Add new video to the Mobile Business system** Description: General information about the video is stored in the system. Input: Video Output: The system (c*omputing annotator*) creates a unique identifier and extracts basic video parameters (length, frame rate, bit rate, ...). A user (h*uman annotator*) adds general information (title, copyright, date of creation). All metadata is stored as a *composite annotation*. **Automatic video analysis** Description: The video analysis process is started. Shot boundaries are detected first; semantic features are detected for each shot in a second step. Input: Video, basic video parameters Output: The results of the video analysis tools (shots and semantic features) are stored in the archive (*computing annotator*). The new data is combined with the data which is already available in the archive (*composite annotation*). **Manual annotation** Description: A user changes, adds or deletes metadata and defined regions of interest. Input: Video, basic video parameters, annotations from the automatic video analysis step Output: Manually annotated data about semantic features and regions of interest are stored in the *Mobile Business* system (h*uman annotator*). **Video adaptation** Description: The information which is required for the adaptation of a video is preserved in the archive. No semantic features are stored for the adapted video, but a reference to the original video is available. Input: Reference to the adapted video, parameters for the adaptation Output: The parameters which have been used for the adaptation are stored in the archive (identifier of the original video, identifier of the adapted video, user preferences, and device characteristics).
Create Media Asset	**Video adaptation** Description: The adaptation tool creates a new adapted video. Input: The original video and its metadata are required for the adaptation process. The characteristic features of the mobile device and the user preferences specify the parameters for the adaptation. Output: The adapted video (m*edia asset*) and the adaptation parameters (c*reation metadata*) are assembled and stored in the *Mobile Business* system.
Publish	**Video adaptation** Description: The adaptation tool modifies a new video to fulfill the user preferences and the specific characteristics of the user's device. Input: The original video (*media asset*) and its metadata (*annotation*) are required for the adaptation process. The characteristic features of the mobile device and the user preferences specify the parameters for the adaptation. Output: The adapted video (*media asset*), the parameters used for the adaptation (*annotation*)
Package	The package process is used for each annotation. The original video and its metadata are grouped and stored in the *Mobile Business* system. The adapted video, the information about the adaptation process and the link to the source video are grouped, too.
Organize	The organize process is used to specify the relations between the original video and its adapted versions. A bi-directional link defines the relationship between these videos.
Distribute	The *Mobile Business* system streams the adapted video to a mobile device.
Premeditate	The premeditate step describes the decision process of the program developers.
Construct Message	The process construct message describes the user interaction. The experience and the ideas of the user are used as input, and the selected parameters are the output of this step.

Table 1: Mapping processes of the *Mobile Cinema* application to canonical processes