UNIVERSIDAD AUTÓNOMA DE MADRID
ESCUELA POLITÉCNICA SUPERIOR

Transformación de imágenes a vídeo

Proyecto de fin de carrera

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Septiembre 2007

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Septiembre 2007

PROYECTO FIN DE CARRERA

Título: *Transformación de imágenes a vídeo*

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Fecha de lectura:

Calificación:

Keywords

Content Adaptation, Image browsing, Image to Video transmoding, Regions of Interest (ROIs), Information fidelity, Visual attention model, Browsing path, Simulated camera movement

Abstract

This master thesis proposes an image to video adaptation system using the human attention model, in order to view large images on mobile displays without a significant loss of information. This approach tries to automate the process of scrolling and zooming through an image with a minimal user interaction by simulating a virtual camera movement through the picture. The process is automatic and the user interaction will be limited to establish some preferences on the video generation.

The application depends on an external module, which is commited to define the regions of interest, which will vary on the domain where this application is used.

The results of the project have been incorporated in the content adaptation framework (named CAIN) developed within the Sixth Framework Program European project IST-FP6-001765 *aceMedia* (http://www.acemedia.org/).

Resumen

El objetivo de este proyecto de fin de carrera es investigar en un sistema de adaptación de imágenes a video, que aproveche el modelo de atención visual humano, para ver imágenes de alta resolución en dispositivos móviles sin pérdidas significativas de información. La aplicación tratará de automatizar el proceso de scrolling y zooming a través de una imagen con una interacción mínima del usuario, que se limitará a establecer sus preferencias en la generación del video.

El sistema de adaptación depende de un módulo de externo, encargado de detectar las regiones de interés, cuyo tipo variará según el entorno que haga uso del sistema de adaptación.

Los resultados del proyecto se han incorporado en la arquitectura de adaptación de contenido CAIN, desarrollada en el proyecto europeo del Sexto Programa Marco IST-FP6-001765 *aceMedia* (http://www.acemedia.org/).

Agradecimientos

Este trabajo no hubiera sido posible sin la valiosa ayuda de todas las personas que han colaborado directa o indirectamente en el proyecto y a las que quedo muy agradecido.

En primer lugar quería agradecer a José María Martínez por la posibilidad que me ha ofrecido de realizar el proyecto de fin de carrera con él y por su trabajo continuo junto a Jesús Bescós por mejorar la carrera de Ingeniería de Telecomunicación en la UAM.

Durante el desarrollo del proyecto ha sido muy importante la ayuda de Víctor Valdés, que me ha echado una mano continuamente a lo largo del proyecto y ha colaborado en el trabajo.

Asimismo quería agradecer a los ocupantes del laboratorio y los miembros del GTI, en especial Víctor Fernández, Javier Molina y Juan Carlos San Miguel, por su ayuda y por todo lo que me he podido reír con ellos.

Y en especial a mi padre, mi madre y mi hermana que son lo más importante para mí.

Fernando Barreiro
Septiembre 2007

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1 Introduction

1.1 Motivation

Communication networks (i.e. mobile, traditional telephone) and Internet are tending towards a unique universal network, which wants to be accessed via different client devices and with very different user preferences. Internet providers need to improve their quality of service by offering adaptive and customized information and content, in order to stand up to the population boom of mobile equipment (PDAs, smartphones, mobile phones) as Internet clients.

In the foreseeable future the present limitations of mobile devices will get more and more reduced, as their performance (bandwidth, computational resources, data storage etc) will slowly converge with the featured performance on desktop computers, and thus becoming more than sufficient to access Internet and fully profit of its multimedia content. The principal remaining limitation will then be the screen size, which can not be increased because of mobility and comfort reasons.

The great deal of information on the Internet presented or shared as images has to be adapted to this limited screen size. Actually, the predominant methods are downsampling, cropping or manual browsing of pictures, what involves information loss in the two first cases and time consumption in the latter case.

1.2 Objectives

A more recent approach to solving the aforementioned adaptation problem of large images to mobile displays, most commonly known as Image2Video[1][2] or Photo2Video [3], tries to convert the input image into a video by simulating a fly-through of a virtual camera which will focus on the regions of interest present in the image. The target of this transmoding[1] is to maximize the information fidelity and the user's experience [4].

The main objective of this project is to design and develop an Image2Video transmoding tool with the purpose of generating an output video, which maximizes the information fidelity at the same time it offers a pleasant presentation. The presentation should take into account some of the viewer's preferences, which s/he will be able to introduce before the execution. A basic diagram of the proposed application is shown in Figure 1-1.

[1] Transmoding is refered in the literature as the adaptation that changes the modality –e.g., image, video, audio, text- of the original media

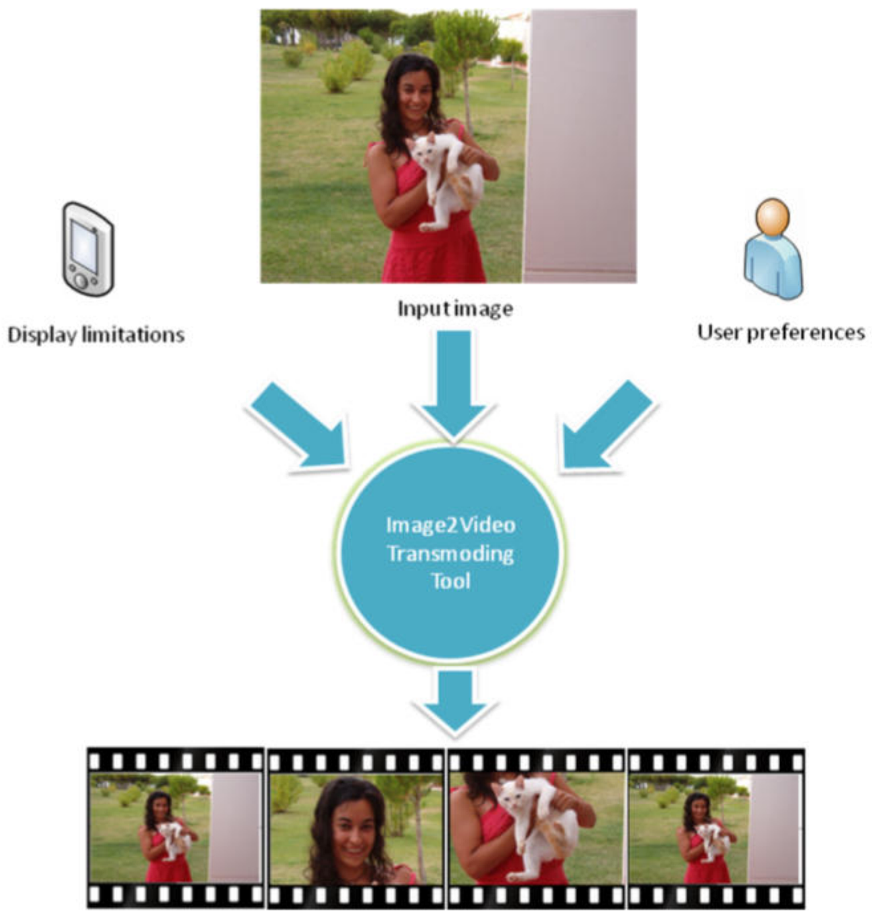


Figure 1-1: Basic Image2Video diagram

The development of the Image2Video adaptation tool implies determining the Regions of Interest[2] –ROIs– in an image, finding the optimal browsing path and generating the final video. The Image2Video application will rely on the external generation of attention objects and will focus on the video generation. The determination of the regions of interest can be done manually using a simple graphical user interface (see Annex B) or automatically by any external ROI generation module. Such an automatical annotation tool has been provided for example by the *aceMedia WorkPackage 4* ([5], [6]), in the form of a convolutional face detector [7].

Although it may look as if the application is designed for leisure purposes, this application can also be used in many different security applications, where a mobile patrol (ambulance, police, private security, firemen) is provided with a mobile device and receives a video generated from a

[2] A Region Of Interest is used in imaging for defining the boundaries of an object. In medical imaging the concept is widely spread and used for measuring for example the size of a tumor. In non-medical imaging, the best known standard is JPEG2000 that specifically provides mechnisms to label the ROIs in an image.

large image taken in the crime/accident scene. So, the mobile patrol is able to prepare for the situation and, given the case, call for reinforcements or a special support unit. This possible system would only need a specific module to identify the desired objects and ROIs and pass this information to the Image2Video application.

1.3 Structure of the present document

This memory is structured in the following chapters:

- **Chapter 1** provides the Introduction(motivation and objectives) of the master thesis
- **Chapter 2** presents other approaches to adaptation of large images to reduced displays, as well as the existing Image2Video transmoding systems. In addition, the algorithms of the external attention focus detection programs, used during the development, will be shortly introduced.
- **Chapter 3** presents the architecture of the system and analyzes the data and external file structures.
- **Chapter 4** describes the implemented algorithms and offers some insight to the decisions, problems and solutions found during the implementation.
- **Chapter 5** covers integration of the system and integration of the application in the CAIN framework. Testing results of the application.
- **Chapter 6** presents some of the conclusions obtained after the development of the system and the possible improvements for future work.

Additionally there are different appendices:

- **Appendix A:** User manual for running the application and execution parameters
- **Appendix B:** Presentation of the graphical user interface’s prototype
- **Appendix C:** Overview of aceMedia’s CAIN system
- **Appendix D:** Description of the OpenCV library
- **Appendix E:** Short description of the Ffmpeg library

1 Introduction

1.1 Motivación

Las redes de comunicación (por ejemplo de teléfono móvil y teléfono convencional) e Internet están tendiendo hacia una red universal, que quiere ser accedida desde diferentes dispositivos y con preferencias de usuario distintas. Los proveedores de Internet necesitan mejorar la calidad de servicio ofreciendo información y contenido adaptado y personalizado para hacer frente al crecimiento explosivo de equipamiento móvil (PDAs, teléfonos móviles inteligentes etc.) como clientes de Internet.

En el futuro previsible, las limitaciones de los dispositivos móviles tenderán a desaparecer rápidamente, al mostrar rendimientos (velocidad de transferencia de datos, recursos de procesamiento y de memoria) cada vez más similares a los de ordenadores de sobremesa y siendo así más que aptos para acceder a Internet y disfrutar del contenido multimedia. La limitación principal, más difícil de solventar, será el tamaño de pantalla, que no puede crecer por motivos de comodidad y movilidad.

La gran cantidad de información compartida en Internet en forma de imágenes debe por ello adaptarse al tamaño reducido de pantalla. Actualmente, los métodos de adaptación predominantes son reducir el tamaño de la imagen (downsampling), recortar la imagen (cropping) y visualización manual (manual browsing) de las imágenes, lo que supone pérdida de información en los dos primeros casos y consumo de tiempo en el último caso.

1.2 Objetivos

Una solución más reciente para realizar la adaptación de imágenes grandes a pantallas de menor resolución, habitualmente conocida como Image2Video[1][2] o Photo2Video [3], intenta convertir la imagen de entrada en un vídeo simulando un recorrido de cámara virtual que se centra en las regiones de interés presentes en la imagen. El objetivo de esta adaptación es maximizar la fidelidad de información y la calidad de visualización [4].

Por ello, el objetivo principal de este proyecto es diseñar y desarrollar una herramienta de adaptación Image2Video que genere un video de salida, que ofrezca a la vez alta fidelidad de información y una presentación agradable. La presentación deberá tener en cuenta algunas preferencias del espectador, que se podrán fijar durante la ejecución de la herramienta. Un diagrama básico de la aplicación propuesta se muestra en Figure 1-1.

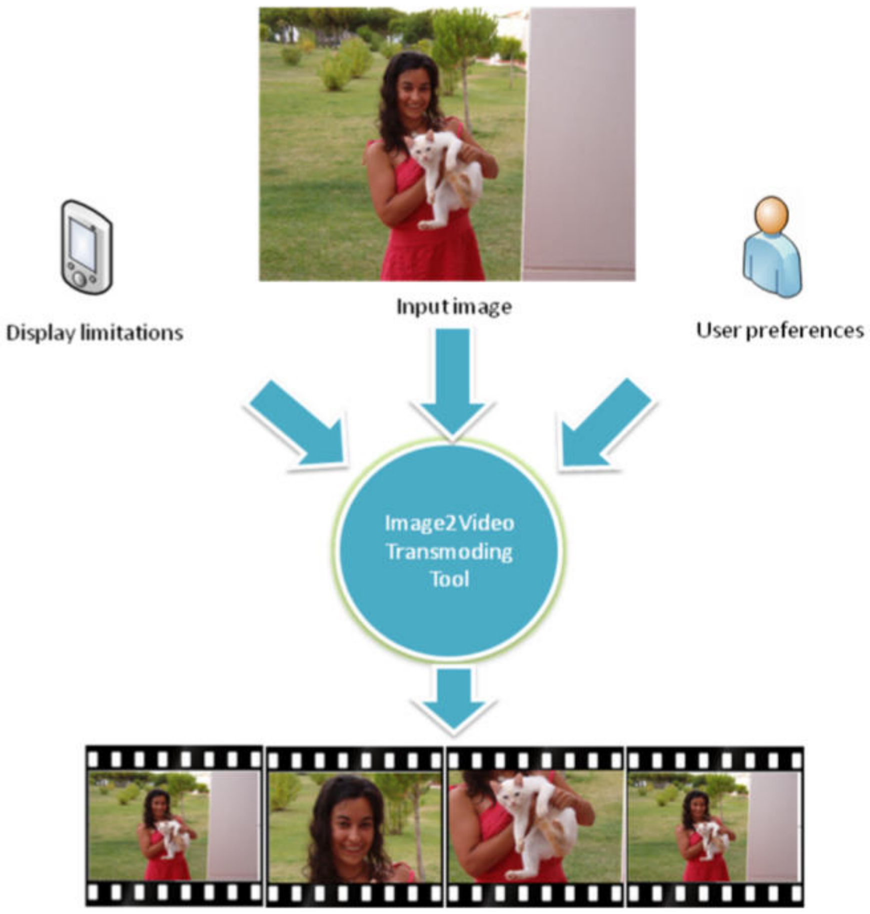


Figure 1-1: Diagrama básico de la adaptación Image2Video

El desarrollo de la herramienta de adaptación Image2Video implica determinar las regiones de interés –ROIs[3]- de una imagen, encontrar el recorrido óptimo y generar el vídeo final. La aplicación dependerá de la identificación externa de los objetos de atención y se centrará en la generación del vídeo. La determinación de regiones de interés se puede realizar manualmente usando una interfaz gráfica (véase Annex B) o automáticamente usando cualquier módulo de determinación de ROIs, como el Convolutional Face Finder facilitado por aceMedia en su paquete de trabajo WP4 ([5] [6] [7]).

Aunque pueda parecer que la aplicación esté dirigida a propósitos de entretenimiento, la aplicación puede usarse en una gran variedad de entornos, como por ejemplo aplicaciones de seguridad y vigilancia, donde una patrulla móvil (ambulancia, policía, bomberos, seguridad privada) está provista de un dispositivo móvil y recibe un vídeo generado a partir de una imagen de

[3] Las regiones de interés ROIs se usan en el campo del tratamiento de imágenes para definir los límites de un objeto. En tratamiento de imágenes médico el concepto es comúnmente conocido y usado para medir por ejemplo el tamaño de un tumor. En tratamiento de imágenes no-médico el estándar más conocido es JPEG2000 que incluye mecanismos de anotación de ROIs en una imagen.

alta resolución tomada en la zona de los hechos. De esta manera, la patrulla móvil puede prepararse para la situación que les espera y, dado el caso, pedir refuerzos o unidades especiales de apoyo. El sistema de seguridad necesitaría un módulo de identificación de ROIs para los objetos deseados y pasar esta información a la aplicación de adaptación Image2Video.

1.3 Organización de la memoria

Esta memoria está dividida en los siguientes capítulos:

- **Capítulo 1:** presenta la introducción (motivación y objetivos) del proyecto fin de carrera.
- **Capítulo 2:** muestra otros intentos de adaptación de imágenes grandes a pantallas de baja resolución, así como los programas existentes de Image2Video. Además se describirán los módulos de identificación de ROIs, particularmente de caras, que se han usado durante el desarrollo de la aplicación.
- **Capítulo 3**: Presenta la arquitectura del sistema y analiza las estructuras de datos internas y de los ficheros externos.
- **Capítulo 4:** Describe los algoritmos implementados y ofrece una visión de las decisiones, problemas y soluciones tomadas durante la implementación.
- **Capítulo 5:** Cubre la integración del sistema durante su desarrollo independiente así como en la arquitectura de adaptación de contenido CAIN. También muestra los resultados de las pruebas realizadas.
- **Capítulo 6:** Presenta algunas conclusiones obtenidas después del desarrollo y enumera las posibilidades de mejora para trabajo futuro.

Adicionalmente hay diferentes apéndices:

- **Apéndice A:** Manual de usuario para ejecutar correctamente la aplicación.
- **Apéndice B:** Presentación del prototipo para la interfaz gráfica de usuario.
- **Apéndice C:** Visión general del sistema CAIN.
- **Apéndice D:** Descripción de la librería OpenCV.
- **Apéndice E:** Breve descripción de la librería Ffmpeg.

2 State of the art

2.1 Visual attention

The Image2Video application is based upon visual attention models observed in humans and takes advantage of some of its limitations [8]. When watching a picture, the viewer centers his attention on some particular regions, which in many applications and papers ([1][3][9][10]) are said to be faces, texts and other saliencies. Nonetheless, it is important to underline that our application is independent of the semantic value of the regions of interest and is not bound to a specific type of visual attention or object detector. The Image2video tool could be used for any possible type of object, for example cars, trains etc. in particular video surveillance systems.

Furthermore, what allows the trading between space and time is the fact that a viewer is only capable of centering his attention on just one of these regions of interest, because the human being is dramatically limited in his visual perception faculties. This can be proven following a simple two step exercise [8]:

1. Look at the centre of figure x and find a big black circle surrounding a small white square
2. Look at the centre of figure x and find a black triangle surrounding a white square

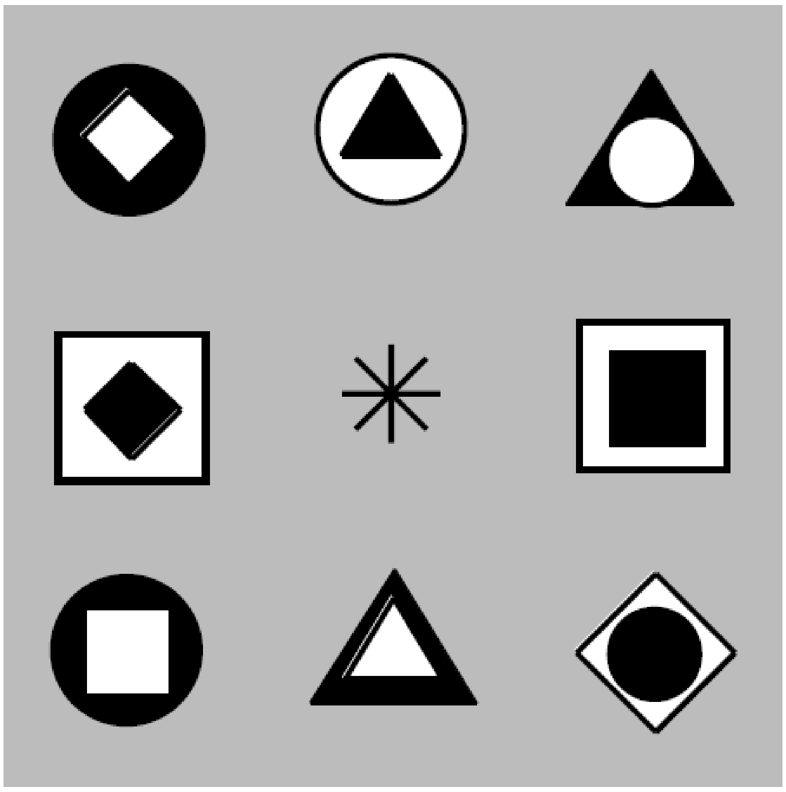


Figure 2-1: Visual ability test (Image taken from [8])

Although you can see all the patterns in the image, your ability to process visual stimuli is limited and you do not know immediately that the first requested item is present at the lower left location and that the second requested item is not present at all. In order to perform the requested task, you have to restrict your visual processing to one at a time. This way, if you obeyed the instructions and kept your eyes on the central fixation point, you changed your processing of the visual input over time without changing the actual input.

The Image2Video uses this fact and shows each attention object individually one after another. To allow a general overview of the image, the whole image will be shown at the beginning and end of the video.

2.1.1 Information fidelity

The term information fidelity introduces a subjective comparison between the information contained in an original image and the information maintained after its adaptation: transmoding in our case. Chen et al. propose a numerical formula for information fidelity in [11], defining its range from 0 (all information lost) to 1 (all information maintained). Thus, the optimal solution of image adaptation will try to maximize this number under various client context constraints. According to these authors, the resulting information fidelity of an image I, consisting of several attention objects, can be calculated as the weighted sum of the information fidelity of all attention objects in I:

$$IF(I) = \sum_{ROI_i \subset I} AV_i \cdot IF_{AOi}$$

AVi: Attention Value
IF_{AOi}: Information Fidelity of the ith attention object
AOi: ith Attention Object in the image
ROIi: Region Of Interest. Determines the spatial region covered by the ith AO

Thus, the Image2Video application has to show all the image's attention objects to reach an information fidelity close to the maximum.

2.1.2 Composite image attention model

Another common definition to most existing papers on Image2Video transmoding is the concept of attention object ([1][11]etc). An attention object is an information carrier that often represents semantic classes such as faces, texts, objects or saliencies in the image. Generally, the viewer focuses mainly on these attention objects, where most of the information that wants to be transmitted is concentrated on an image. The most complete set to determine an attention object is

$$\{AO_i\} = \{(ROI_i, AV_i, MPS_i, MPT_i)\}, 1 \le i \le N$$

where

AOi: ith Attention Object in the image
ROIi: Region Of Interest, which mainly determines the spatial region occupied by the ith AO
AVi: Attention Value
MPSi: Minimal Perceptible Size of AOi
MPTi: Minimal Perceptible Time of AOi
N: Number of attention objects

As stated in the definition, an attention object needs a minimal spatial resolution and a minimal displaying time in order to be correctly recognized. When displaying the attention objects of an image in the generated video, these values have to be taken into account somehow.

Generally, if possible, the regions of interest will be displayed in their full original resolution. If the region's size compared to that of the display is small, the attention object can be interpolated and displayed in a greater size. The maximal interpolation will be left to the user, who can decide and establish his preferences. If he desires to zoom in too much, the attention object may appear pixelated.

In the opposite case, when the attention object is greater than the display, it has to be downsampled or split in more segments. Faces will not be split, as it is more pleasant for the viewer when they are presented entirely.

2.2 Other approaches to the adaptation of large images to reduced displays

2.2.1 Direct downsampling

Image downsampling clearly results in an important information loss, as the resolution is reduced excessively in many cases. Downsampled images can be compared to thumbnail images, which are used to recognize an image, but never to view the entire information, as the low resolution does not allow the viewer to distinguish details.

2.2.2 Cropping

There are two different cropping modes, blind and semantic, which differ by analyzing previously or not the semantic content in the image.

The blind cropping approach always takes the central part of the image, cutting off the borders of the image, where the major part of the information could be concentrated.

The semantic cropping based image adaptation, as described in [11], tries to select the part of the image where most of the information is concentrated, in order to maintain the highest information fidelity possible. Nevertheless, this strategy assumes that most of the information is confined to a small part of the image, which is not true for most real images. When trying to adapt the image to a small display, this approach has either to select a very small part of the image or has to downsample the segment. The result does not seem very optimal.

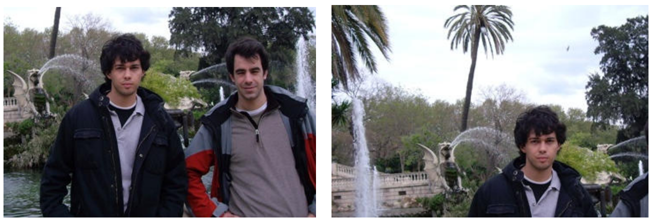
2.2.3 Manual browsing

Manual browsing avoids information loss, but is often annoying for the viewer, as he has to scroll and zoom through the image by himself and makes him loose time. The Image2Video approach simulates and automatizes the process of manual browsing.

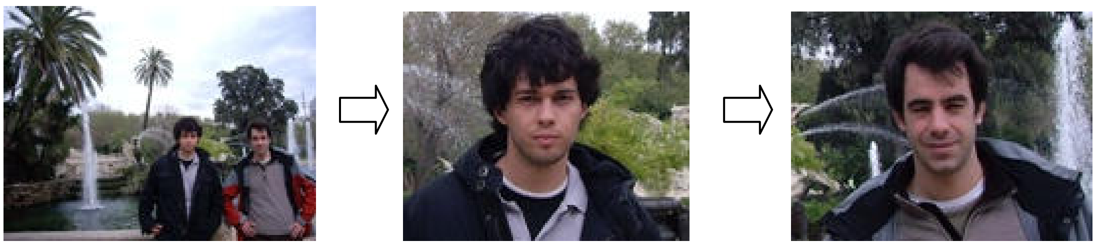
A result example of the three aforementioned approaches can be observed in the following pictures, which simulate these procedures. It is important to realize, that the example has deliberately been chosen to confine the important information in a relatively small, not centric area.

a) Original image

b) Downsampled image



c) Cropped image with and without prior semantic analysis (Semantic vs blind cropping)



d) Keyframes in manual browsing or in automated Image2Video

Figure 2-2: Comparison between the different existing approaches

2.3 Attention focus detection

As already mentioned before, the Image2Video application relies on the external image analysis and ROI generation, separating clearly the image analysis from the ROI based content adaptation. To underline this fact, from now on we'll divide the Image2Video application into ROIExtraction plus ROIs2Video (video generation out of an input image and a set of ROIs), being this work centered in the ROIs2Video development.

The transmoding tool is focused mainly on the video generation, independently on the generation of semantic values of the ROIs. This way, any external program can use a desired object detector and pass the ROI specification file to the ROIs2Video algorithm.

In the deployment of the Image2Video CAT (Content Adaptation Tool) for the aceMedia project, the workpackage WP4 (D4.2 and D4.7 deliverables) provides an attention object detector that is scoped to person and face detection/recognition [5]. Other applications, like surveillance systems, could use the ROIs2Video algorithm adding for example a detector for any specific object (for example: cars, trains, abandoned objects…), generate a video using the analysis data and send the video over to a mobile device carried by a security guard.

Generally, for most common applications, the semantic analysis is based on face and text, because most visual attention models (see [1] [3] [9] [10]) state that these are the objects an average viewer concentrates on in entertainment applications.

The following sections will therefore offer a brief introduction into the used detection algorithms for faces.

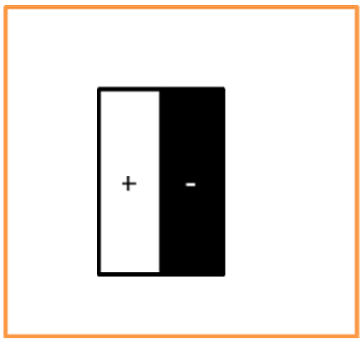
2.3.1 The Viola-Jones face detection method

The Viola-Jones method for face detection (available in OpenCV –see Appendix D-), proposed by Paul Viola and Michael Jones [12], is based on the training of a classifier with positive and negative examples.

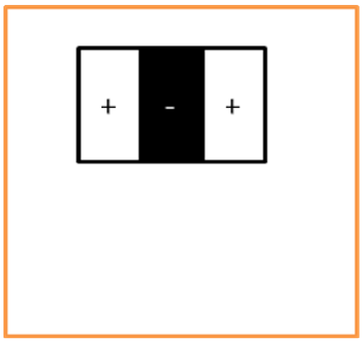
2.3.1.1 Features

This classifier uses simple rectangular features evolved from Haar wavelets (pairs of dark and light rectangles), thus called Haarlike features. Three different kinds of features are used:

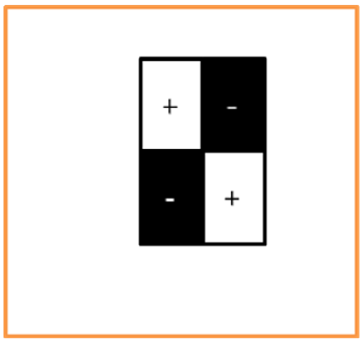
- Two-rectangle features: The value of a two rectangle feature is the difference between the sums of the pixels in each rectangular region. The rectangles can be horizontally or vertically adjacent and have to be the same size (Figure 2-3 a.).
- Three-rectangle features: The value of such a feature is the sum of the pixels in the outside rectangles minus the sum of the pixels in the center rectangle. (Figure 2-3 b.)
- Four-rectangle features: The value is computed as the difference between diagonal pairs of rectangles as shown in Figure 2-3 c



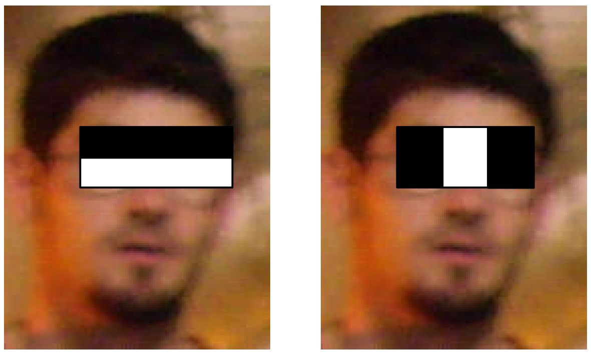
a. Two-rectangle feature



b. Three-rectangle feature



c. Four-rectangle feature

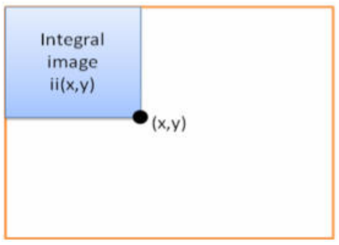


d. Weak classifiers

Figure 2-3: Example rectangle features

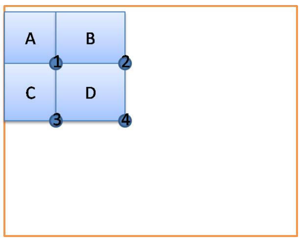
The base resolution of the detector is 24 x 24 pixels, which tends to the smallest window that can be used without losing important information.

For the calculation of the rectangle features, an intermediate representation for the image – the integral image ii – is used:



$$ii(x,y) = \sum_{x' \le x, y' \le y} i(x',y')$$

a) The value of the integral image at point (x,y)



$$\sum_D pixels = ii(x_4,y_4) - ii(x_2,y_2) - $$
$$- ii(x_3,y_3) + ii(x_1,y_1)$$

b) Calculating the rectangular sum using the integral image

Figure 2-4: Integral image

Using the integral image, the rectangular sum of pixels can be calculated in four steps (see Figure 2-4 b.).

2.3.1.2 AdaBoost machine learning method

Using the rectangular features and a set of positive and negative examples, a classification function can be learned. There are 160.000 rectangles associated with each image sub-window. Each feature can be computed efficiently, but computing the entire set is completely unfeasible. In the Viola-Jones classifier, a variant of AdaBoost [13], short for Adaptive Boosting, is used to select the features and to train the classifier.

AdaBoost combines many weak classifiers in order to create a strong classifier. Each weak classifier finds the right answer only a bit better than 50% of the times (almost a random decisor). The final strong classifier is a weighted combination of the weak classifiers, being the weights distributed initially uniformly and then re-weighted more heavily for the incorrect classifications as shown in Figure 2-5.

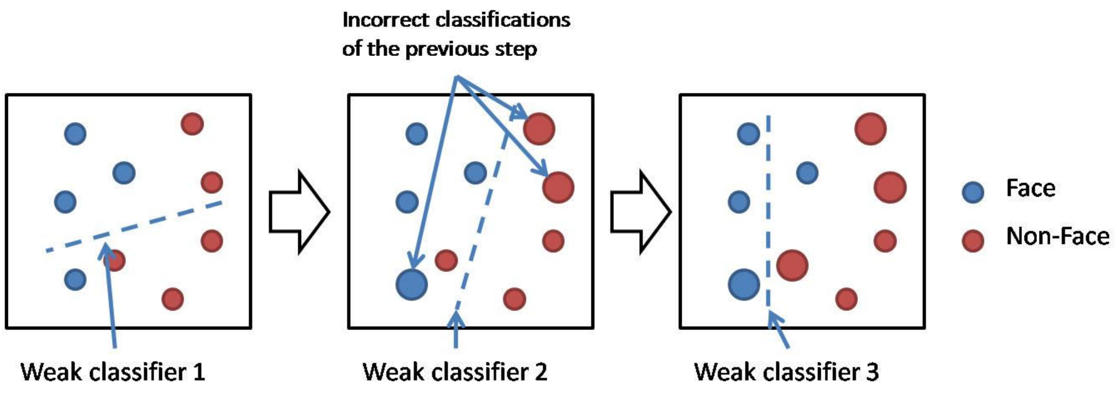


Figure 2-5: 1. Initially, uniform weights are distributed through the training examples. 2&3. Incorrect classifications are reassigned with more weight (shown as bigger dots). The final classifier is a weighted combination of the weak classifiers

Viola and Jones combine weak classifiers as a filter chain (see Figure 2-6), where each weak classifier consists of a single feature. The threshold for each filter is set low enough to pass almost all the face examples. If a weak classifier filters a subwindow, the subwindow is immediately tagged as “no face”.

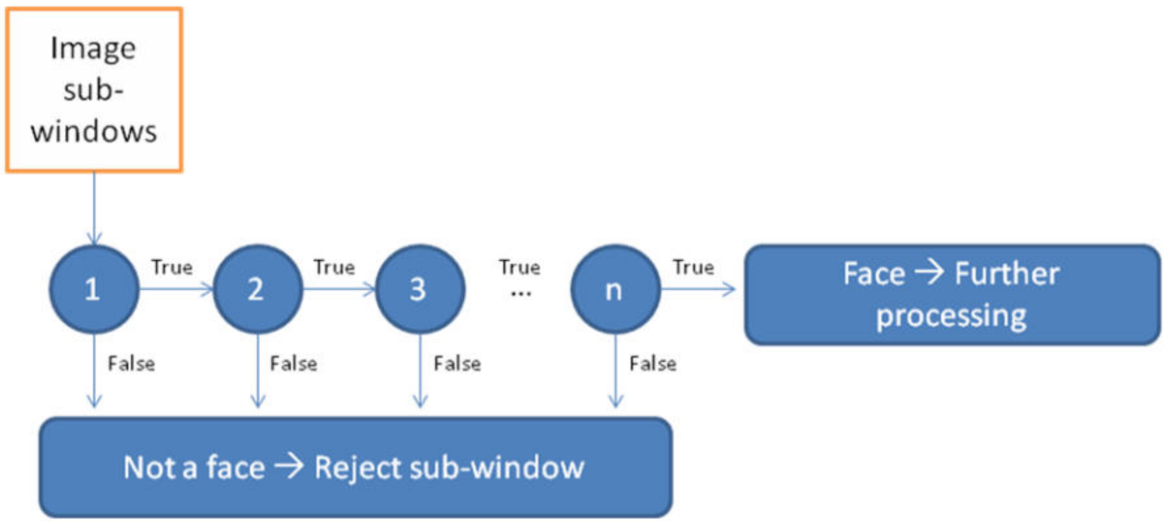


Figure 2-6: The classifier cascade is a chain of single-feature filters

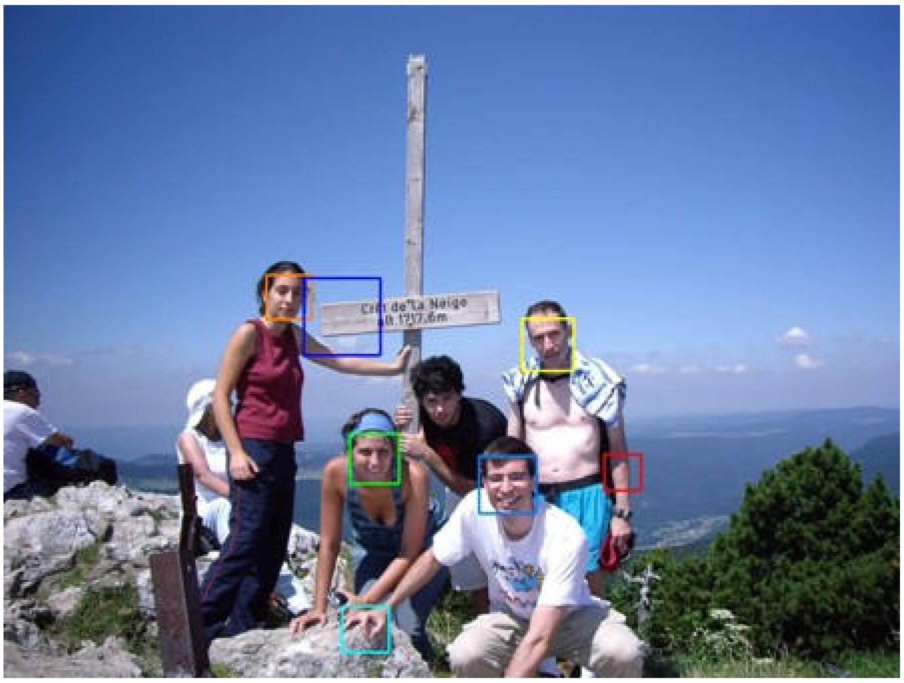
2.3.1.3 Scanning an image

To search the object across the image after the training, a search window scans the image looking for the object. As the object does not have to be of the same size as the trained examples, the search window (not the image itself) has to be resized and the procedure repeated several times.

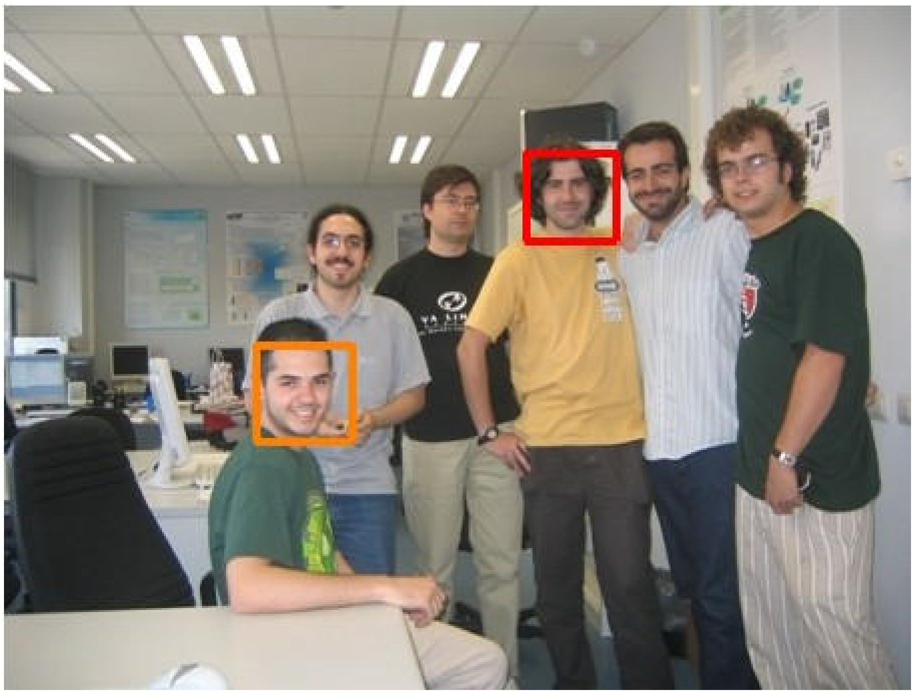
2.3.1.4 Detection results and general comments

The Viola-Jones classifier was used at the beginning of the Image2Video application’s development in order to have automatical ROI annotation and not have to annotate the ROIs manually. The face detector does not detect 100% of the faces, especially not when the head is turned or a part of the face covered by something. What is more annoying for the Image2Video application is that the Viola-Jones face detector frequently classifies erroneously parts in images as faces, that really are not. When the simulated camera stops at these parts of the image the viewer gets confused.

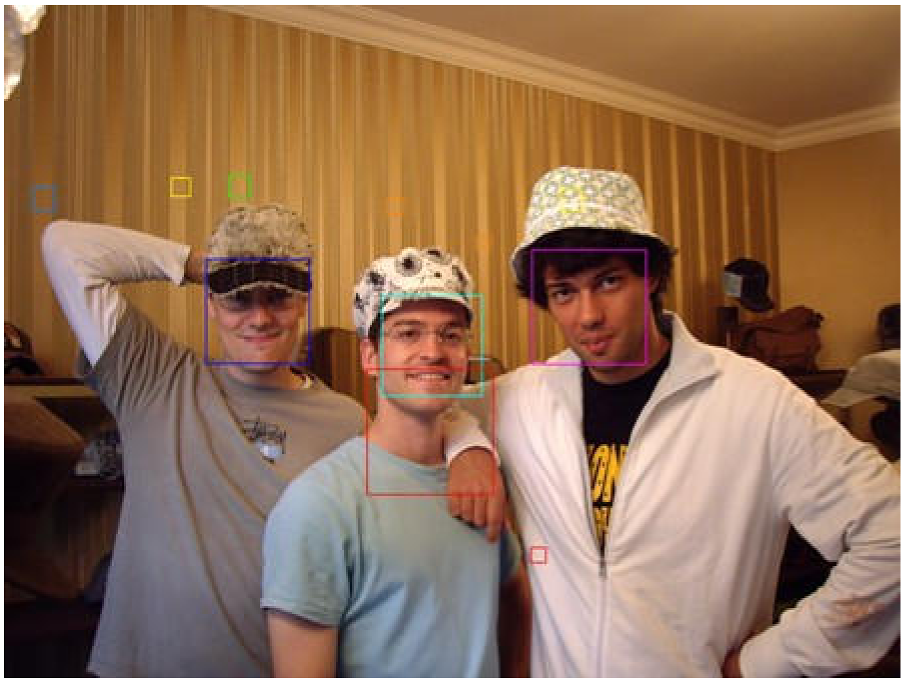
The following figures are examples of real executions of the Viola-Jones face detector using the trained data from the file *haarcascade_frontalface_alt.xml*.



a) 4 detected faces, 1 not detected face, 3 erroneously detected faces



b) 2 detected faces, 4 not detected faces, 0 erroneously detected faces



c) 3 detected faces, 0 not detected faces, 6 erroneously detected faces

Figure 2-7: Performance of the Viola-Jones detector

Just out of curiousity, the Viola-Jones seems to be the first real-time frontal faces detector system running at 15 frames per second on a conventional PC. OpenCV provides the code for testing this system with a webcam and it works fairly well, although it sometimes detects parts of the background as faces.

The Viola-Jones algorithm can be adapted to detect other objects, for example hand detection, which has been implemented at the University of Ottawa changing the training data and haarlike features.

2.3.2 Face detection in aceMedia: the Convolutional Face Finder

Face detection in aceMedia is based on Cristophe Garcia and Manolis Delakis' Neural Architecture for Fast and Robust Face Detection [7]. Using the Convolutional Neural Network, called Convolutional Face Finder in this article, this research line aims to achieve high detection rates with a low rate of false positives, even in difficult test sets with faces that can be rotated ±20 degrees in image plane and turned up ±60 degrees.

2.3.2.1 Convolutional Neural Network Architecture

The Convolutional Face Finder consists of six layers plus the retina that receives a matrix of 32x36 pixels that wants to be classified as face or non-face (see Figure 2-8). The layers are divided into two alternated C_i and S_i layers and finally followed by two N_i layers:

- The C_i layers are convolution layers, responsible for detecting face features.
- The S_i layers follow the C_i layers and reduce the precision of the position in the feature map, because only the approximate, relative position of the features in a face is important.
- The N_i layers contain classical neural networks and decide the final classification, based on the extracted features in the previous layers.

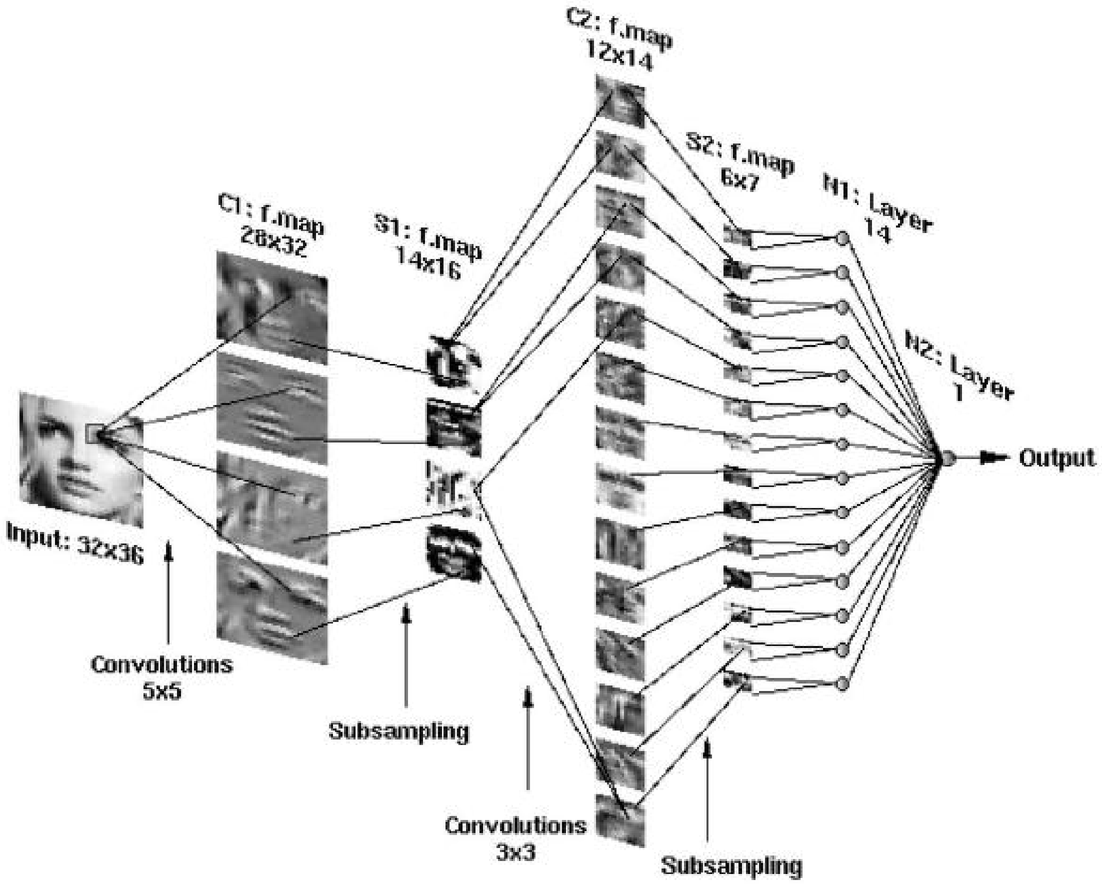


Figure 2-8: The Convolutional Face Finder (Image copied from [7])

2.3.2.2 Training the parameters

Each layer has trainable coefficients for extracting and classifying the features:

- C_1: 104 trainable parameters
- S_1: 8 trainable parameters
- C_2: 194 trainable parameters
- S_2: 28 trainable parameters

- N_1: 602 trainable parameters
- N_2: 15 trainable parameters

These parameters are trained with a set of 3702 different face areas, showing faces in uncontrolled natural environments. The faces are manually annotated to indicate the eyes and mouth positions and cropped to the 32x36 pixel size of the retina. The faces passed to the retina deliberately include the borders of the face, because the system is fed with more information and thus will reduce the false positives. Note that the size of the retina is bigger than the size of the images in the Viola-Jones method (24x24 pixels).

The parameters also want to be trained with non-face images, what is more difficult, as any random 32x36 image not containing a face can be used as a non-face example. Therefore the bootstrapping algorithm is used, that trains the system with false positives found in a set of 6422 non-face images and retraining the system.

2.3.2.3 Face localization

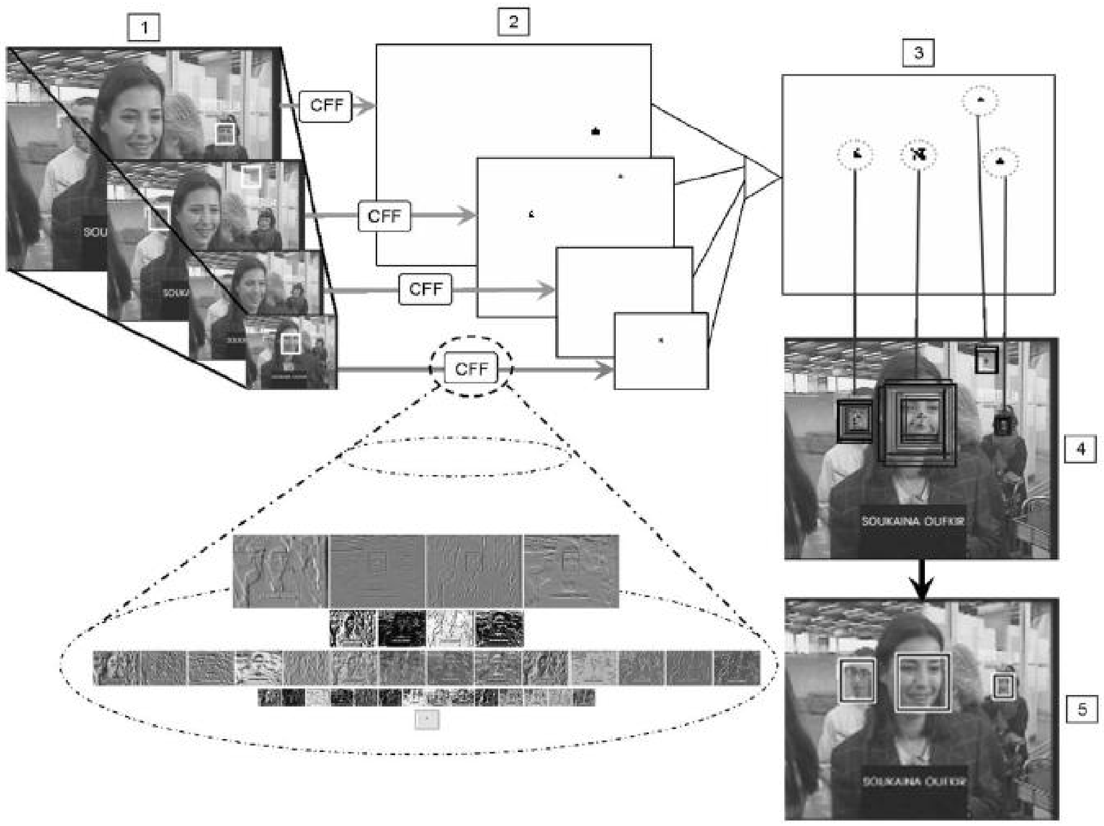
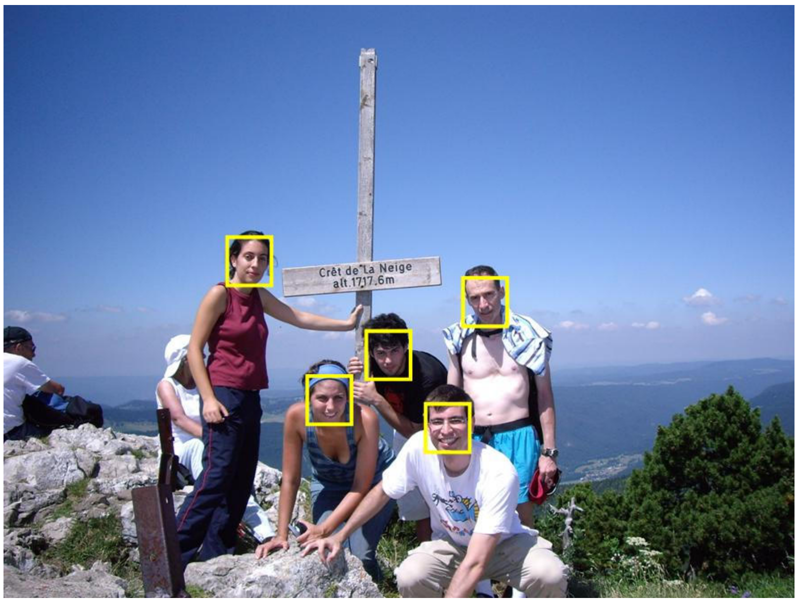


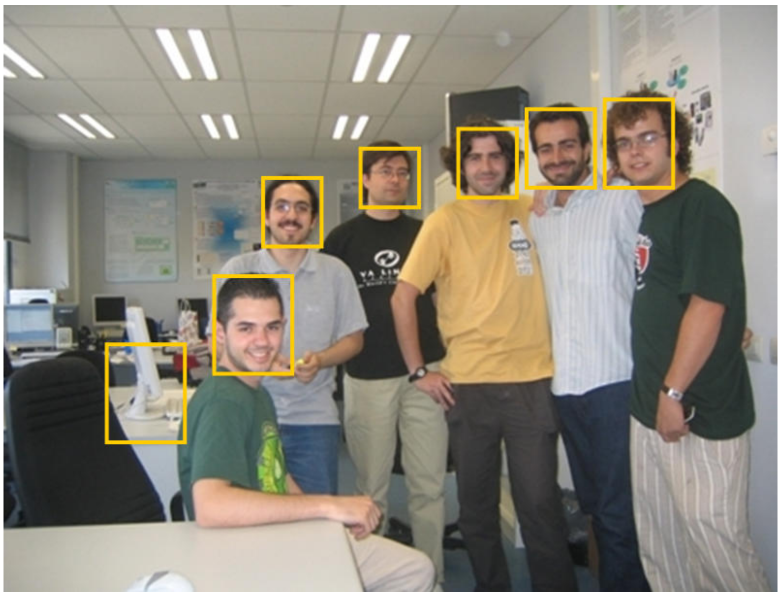
Figure 2-9: Steps in face localization (Image copied from [7])

As seen in Figure 2-9, in order to find the faces with resolution close to 32x36, a multiscaled pyramid of the image is created. For each image in the pyramid, the Convolutional Face Finder is applied, resulting in a set of face candidates in the original scaled image. Finally a neural filter is applied to the fine pyramid centered at the candidates and, depending on the percentage of positive answers each candidate is classified as Face or Non-face.

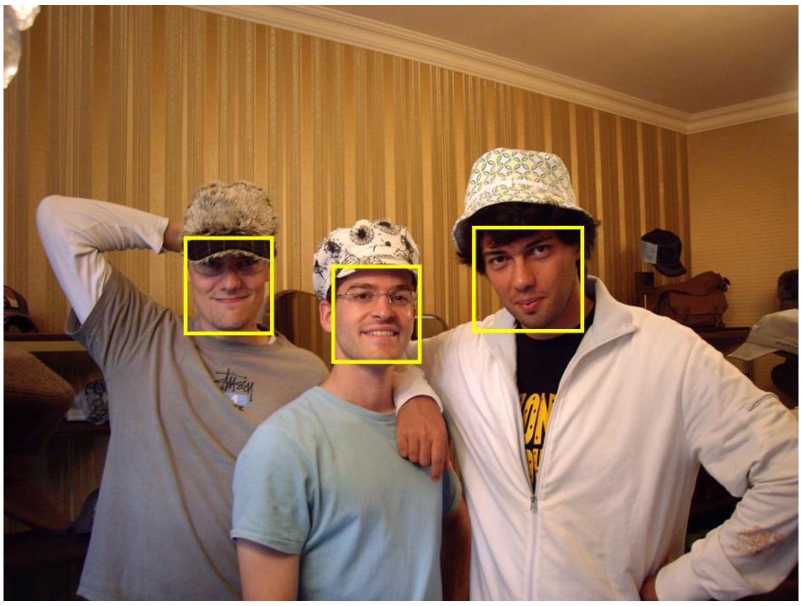
2.3.2.4 Detection results



a) 5 detected faces, 0 not detected faces, 0 erroneously detected faces



b) 6 detected faces, 0 not detected faces, 1 erroneously detected faces



c) 3 detected faces, 0 not detected faces, 0 erroneously detected faces

Figure 2-10: Performance of the Convolutional Face Finder

2.4 Existing Image2Video approaches

In this chapter former Image2Video applications will be presented and compared. Principally, there are three existent approaches, omitting other applications that basically generate video slideshows adding special effects, soundtracks etc. (such as for example Microsoft's Photostory (see Figure 2-11)).

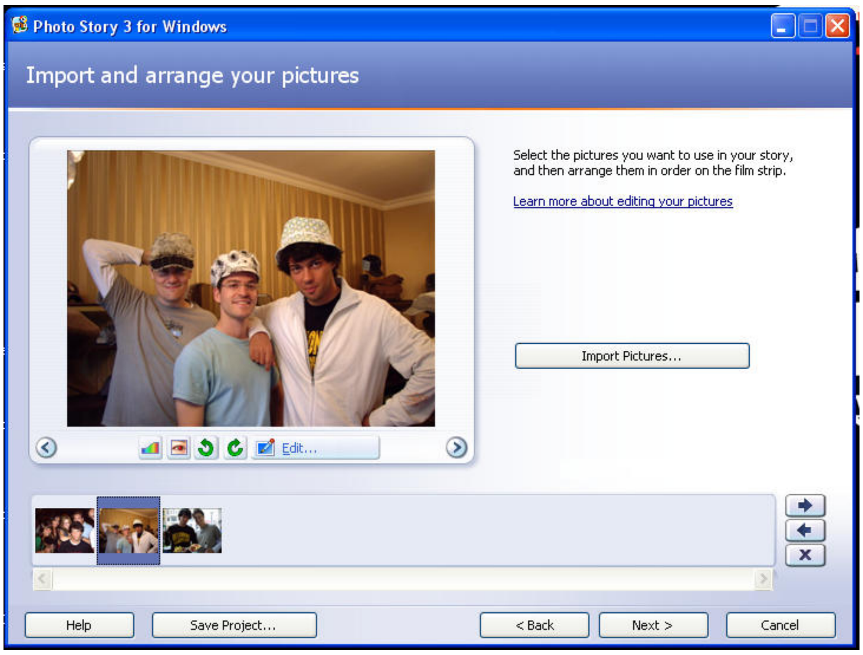


Photo Story 3 for Windows
Import and arrange your pictures
Select the pictures you want to use in your story, and then arrange them in order on the film strip.
Learn more about editing your pictures
Import Pictures...
Edit...
Help
Save Project...
< Back
Next >
Cancel

Figure 2-11: Microsoft's Photostory initial dialog

2.4.1 Image2Video adaptation system - IST Lisbon

This project [1] has been led at the Instituto de Telecomunicações in Lisbon by Professor Pereira and two of his students, Baltazar and Pinho. The developed application appears to be an alternative implementation of the described in Liu et al's article [9], discussed in the next section.

The authors divide their Image2Video application in 4 steps as shown in Figure 2-12.

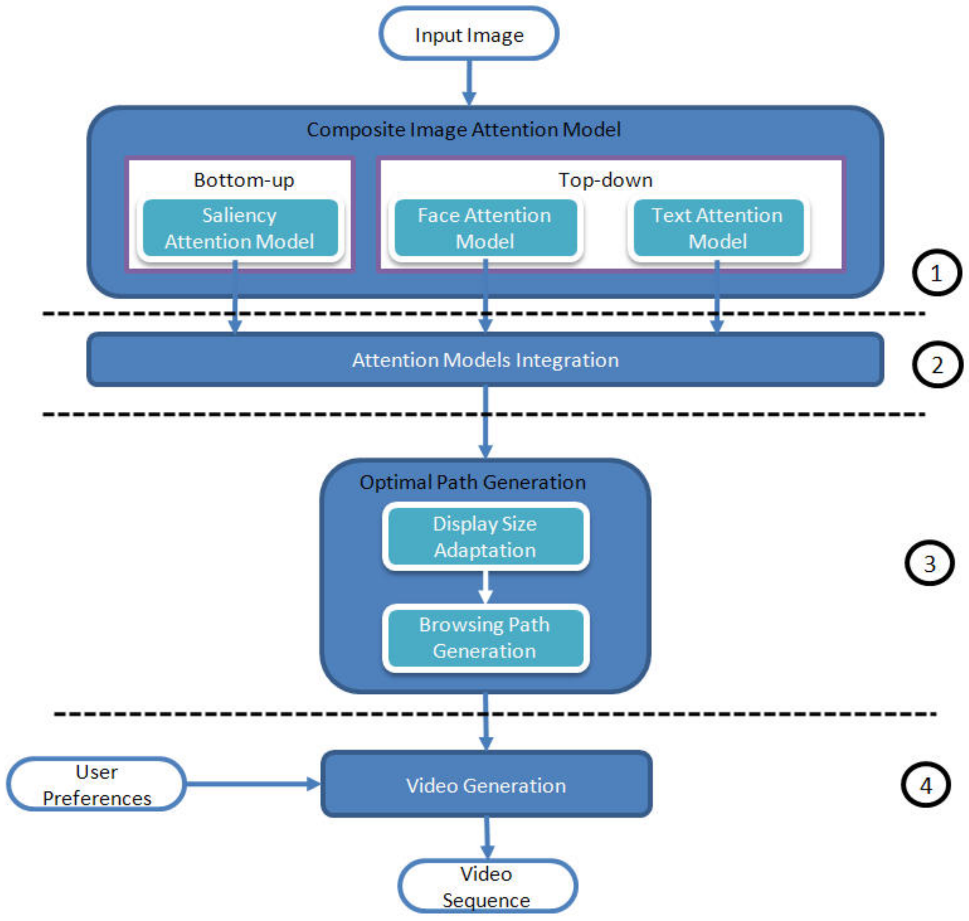


Figure 2-12: System architecture

1. *Composite Image Attention Model*

The objective of this step is to determine the attention objects, which will be classified into saliencies, faces and text. For this task they build upon previous work done in Pereira's group, using a face detection solution integrating automatic and user assisted tools [14] and automatic text extraction [15]. They consider faces as one of the semantic objects most likely to captivate the attention and text as a rich font of information that ties the human mind's focus.

2. *Attention model integration*

Step 2 is an integration stage, where the authors pretend to create a unique attention map using the previously identified attention objects and solving the possible spatial overlappings. The criteria are:

- Face-Text integration: Faces and text have completely different semantic values and should therefore not be integrated together. The authors state that the cases where text and faces overlap are due to inexact definitions of the bounding boxes of the detected ROIs.
- Face-Saliency integration: A detected face and a detected saliency are most likely to represent the same ROI, a face, if the face contains a significant part of the saliency. This condition can be expressed as:

$$\frac{area(ROI_{face} \cap ROI_{saliency})}{area(ROI_{saliency})} \geq 0.25$$

- Text-Saliency integration: Equivalently, a detected text and a detected saliency are most likely to represent the same ROI if

$$\frac{area(ROI_{text} \cap ROI_{saliency})}{area(ROI_{saliency})} \geq 0.25$$

Besides the integration of different detected attention objects, in this stage the authors also assign the order of importance of the attention objects: the attention values. The type of attention object implicates a certain weight:

$$W_{Saliency}=0.2$$

$$W_{Text}=0.35$$

$$W_{Face}=0.45$$

According to their experiments, the attention value AV_i of each object is modified according to the weight of the type:

$$AV_{final} = AV \cdot W_m$$

Attention objects with a final AV that falls under a certain threshold will be eliminated, while AOs with higher AVs will enjoy higher priorities in the next stages.

3. *Optimal Path Generation*

In this stage, the path used to display the video will be generated in two steps:

i. Display size adaptation: The attention objects ideally want to be displayed in the video with the same spatial resolution as the image (i.e. one pixel on the image wants to be displayed as one pixel on the video). Therefore, big attention objects (except faces) have to be split in smaller parts that fit the display size. Small attention objects can ocassionally be grouped with others.

ii. Browsing Path Generation: This mechanism determines the order in which the attention objects will be displayed. Attention objects are displayed following the order of their AVs and taking into account the travelled distance somehow in order to avoid travelling back and forth. However, this algorithm is not explained in detail and lacks clarity.

4. *Video Generation*

In this stage the video sequence is generated according to three modes:

i. Normal mode: All the attention objects are shown

ii. Time based mode: The video cuts all the attention objects that appear after a certain time limit.

iii. Amount of information based mode: The video sequence will show only the most important attention objects until a certain information percentage limit is reached.

2.4.2 Rapid Serial Visual Presentation – Microsoft Research Asia

Microsoft Research Asia has published a variety of articles principally under the authory of Xie, Ma and Zhang [9] [10], which use the exact term *Rapid Serial Visual Presentation* for the result output of their system. The Rapid Serial Visual Presentation can be regarded as a type of video which displays serially the different parts of the image, each for a short period of time and scrolls between the regions, though it is not saved as a proper video file.

The Image2Video system developed at the IST, presented in the previous chapter, clearly is built upon the ideas presented in these articles. The similarity between both system architectures results evident when comparing both frameworks (see Figure 2-12 and Figure 2-13). Thus, this section will only comment briefly some the Rapid Serial Visual Presentation, omitting details.

In the articles Xie, Ma and Zhang focus on the description of the browsing path generation and leave the image modeling stages (attention object detection) apart. The authors distinguish between the fixation status, in which a particular ROI is exploited, and the shifting status, where the presentation shifts between one ROI and the next one. The shifting between two ROIs is simulated by traveling the straight lines that link the attention objects and never exceeding maximal panning or zooming speeds.

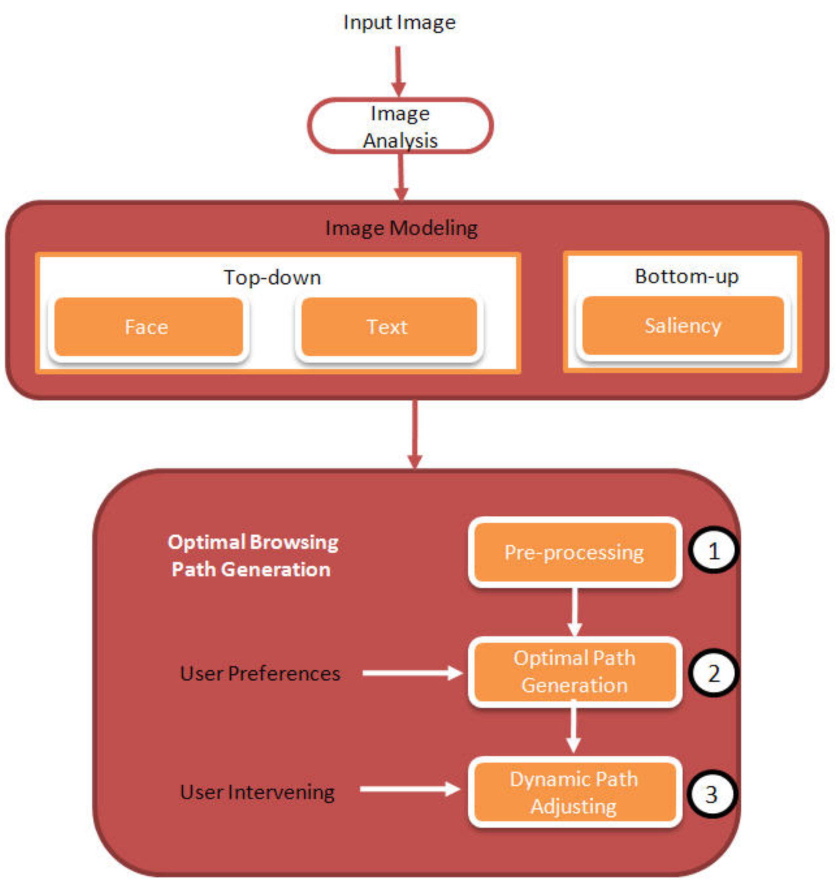


Figure 2-13: System architecture

1. *Preprocessing the ROIs*

In order to find the optimal path, it is essential to preprocess the ROIs:

- splitting attention objects larger than the screen size
- grouping together nearby attention objects to reduce the computational complexity of the browsing path generation algorithms

2. *Optimal Path Generation*

Similar to the time based and information based modes in the IST's Image2Video application, Xie and his colleagues define the *Skimming* and the *Perusing* mode, which obtain the order of the ROIs using a backtracking algorithm to enumerate the possible paths and find the best among them. In the case the user wants to view all the information, the problem of ordering the ROIs can be seen as the Traveling Salesman Problem and an approximation algorithm can be applied to find a fast but suboptimal solution.

3. *Dynamic Path Adjusting*

The system also allows the user to stop the browsing process, look at the image independently and resume the automatic presentation afterwards.

2.4.3 Photo2Video – Microsoft Research Asia

The Photo2Video method [3] appears to be Microsoft Research Asia's evolution of the Rapid Serial Visual Presentation, including many new features and options. From the presented systems, it appears to be by far the leading system with the most evolved characteristics. It aims to be more than just a simple transmoding tool, and targets the capacity of generating musical stories out of image series. The general system's flowchart, designed to succeed such features, is presented in Figure 2-14 and the detailed description of the stages will be included next.

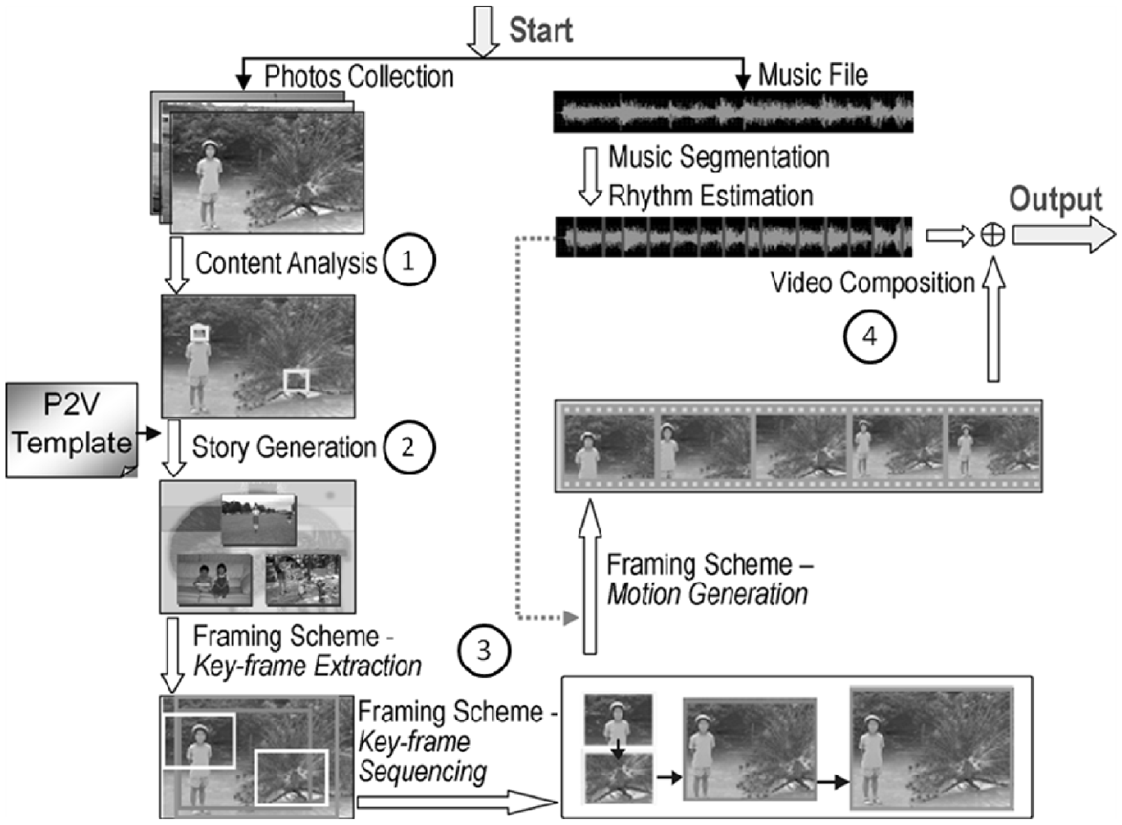


Figure 2-14: Flowchart of Photo2Video taken from [3]

1. *Content Analysis*

The content analysis applies a set of image and music content analysis algorithms.

i. **Image analysis**: The images are first ordered by timestamps if available and by filenames otherwise. The images are passed through a quality filter that removes images with a quality measure under a predefined threshold and through a duplicate detection filter that removes similar photographs.

Next, face and attention detection are applied to estimate the attention objects on each specific image and thus to establish the ROIs. The face detection can be accompanied by some external annotation in order to be able to generate a film for an individual person out of a digital photo album.

With the information gathered during the face and attention detection, each photograph can be semantically classified into different established groups, such as no-people, portrait, multiple people, group photograph…

ii. **Music analysis**: The video presentation will be accompanied by incidental, synchronized music. The functioning of the alignment between music and video will not be described in this document.

2. Story Generation

As the name already anticipates, this stage attempts to generate a story line based on generating Temporal Structure Layers. It is completed in three steps:

i. Photograph selection and grouping

ii. Specify leading actor

iii. Advanced Story Generation, where the user is able to interact, undo previous automatic actions, provide scene titles and impose some other desires.

The result of this stage is a group of XML files representing a timeline and the moments each specific action starts and ends.

3. Framing scheme

The framing scheme is divided in Key-frame Extraction, Key-frame Sequencing and Motion Generation.

The Key-frame Extraction defines the origin and destination frames of the simulated camera movement, in order to generate smooth motions. The authors define different types of frames, classificating them by the area of the picture they include: Full, medium and close-up frames

The Key-frame Sequencing will establish the order in which these extracted key-frames are presented (for example Full frame→ Medium frame → Close-up frame).

Finally, the Motion Generation step is in charge to simulate the virtual camera movement between the key-frames with the principal target of generating a smooth motion. The necessary controls needed for this task are:

- Panning Motion Trajectories: The trajectories will be generated by cubic interpolating splines with the smallest maximal curvature.
- Speed Control: Determining the average speed control, the local panning speed control and the local zooming speed control

The output of this step is the video information that is added to the music file, in order to generate the complete, composed video.

2.4.4 Conclusions

2.4.4.1 Differences between the Image2Video approaches

The presented articles have shown a general insight into the existing Image2Video applications. As anticipated before, the Photo2Video application seems to be the most advanced application in image to video transmoding, presenting the most extense prior processing and explaining in detail the followed algorithms to generate the simulated camera motion.

IST’s approach does not include striking new features and seems to be an alternative implementation of Microsofts Rapid Serial Visual Presentation (as far as the articles show). Both articles present a similar previous semantic analysis of the image, the same preprocessing of the detected ROIs and finally present a similar browsing path generation. Both articles don’t mention how to generate the simulated camera motion, how they interpolate the curves or how they control the speed of the movement. This leads to think that they haven’t focused their work on these aspects, but have concentrated on the ROI generation and processing (grouping, splitting...). The Time Based and Amount of Information Based (or Perusing and Skimming mode) video generations don’t appear to be very useful or optimal solutions, as a certain amount of information can be cut of the video almost randomly.

Microsoft’s Photo2Video application, on the contrary, is a more complete article. The approach is an entertainment application to generate video-albums with incidental music to be viewed on a personal computer, and therefore needs a strong content analysis, semantic classification and story generation, in order to generate meaningful video albums. This information processing is useful for leisure-time applications, but unnecessary for other particular uses, such as security and surveillance systems. A difference to the other approaches is that the Photo2Video application is not designed to generate small sized videos for mobile devices and does not talk explicitly about the possibility of adapting the video to different screen sizes. The motion generation is discussed in detail and has served as a guide for some of the decisions taken for the work of this master thesis.

2.4.4.2 Contributions of this master thesis

Our approach will rely on an external information source that establishes the ROIs that have to be shown and assigns an importance or relevance (both terms will be used indistinctly) factor to each ROI so it is displayed proportionally to its relevance. All the applications presented above include fixed ROIExtraction modules (i.e. face and saliency detectors) and differentiate the presentation according to the ROI type. Our work pretends to be a more general approach for the ROIs2Video system and to concentrate on a quality, user customizable video generation that can be generated independently on the prior semantic analysis. The planned contributions in the research field of Image2Video adaptation are:

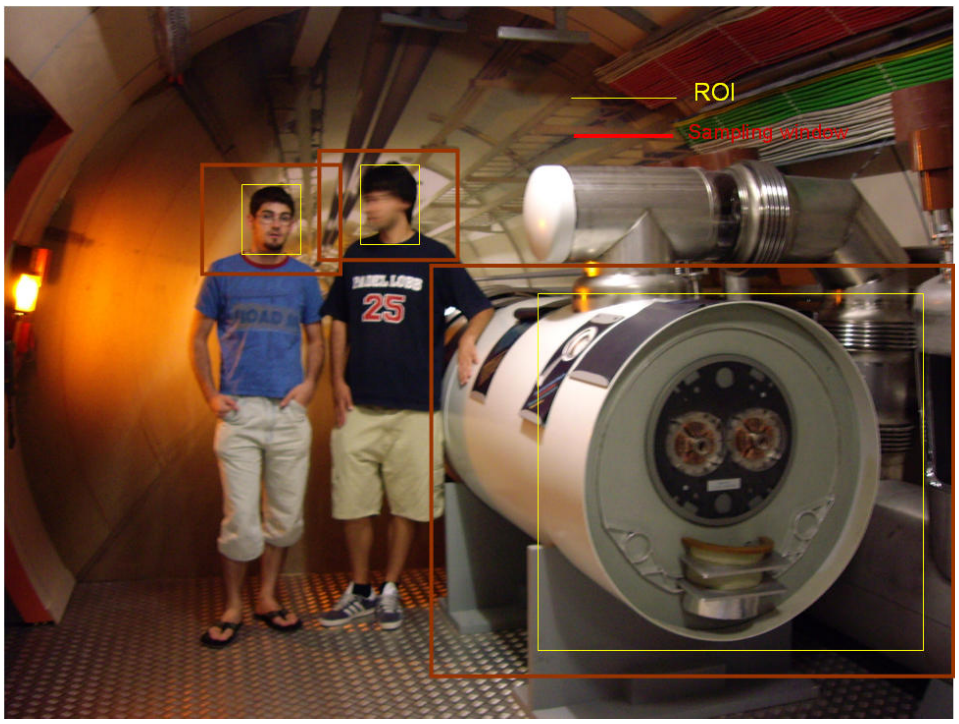
- Video quality and motion smoothness
- General and open implementation, independent on the prior ROI detection and semantic analysis.
- User customizable video. The user can set his preferences in:
    - Camera motion speed
    - Curvature of the camera motion
    - Maximal zoom-in
    - Video bitrate and used codec. This options offer the possibility of generating lighter or heavier videos, leaving it to the user to find a compromise between the video coding quality and its size. For example if the video will be sent through a low-bandwith network the user is able to generate a video with low bitrate.
- Possibility of using automatic or manual methods:
    - Automatic or manual ordering of the browsing path.
    - Using the manual annotation GUI, together with the manual ordering and the other available options, is a powerful and fast tool to create completely personalized videos
- Video generation at any frame resolution, as long as the resolution is lower than the image resolution.
- New research in alternative algorithms to the ones used in the articles.

3 Design

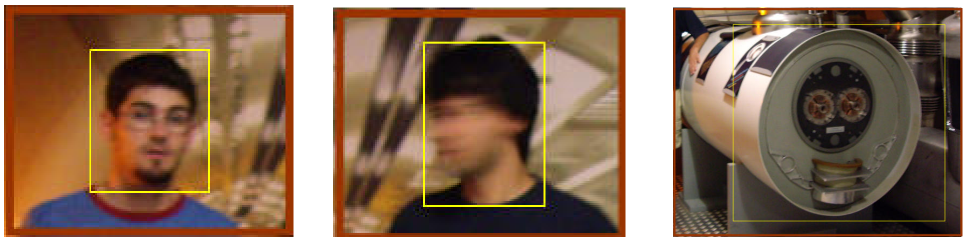
3.1 Definitions

Before starting describing the architecture, it is important to establish some definitions to avoid misunderstandings and unify some concepts.

- **Window/Sampling window**: Rectangle of pixels copied from the original image. It is the part of the original image captured by the virtual camera (see Figure 3-1 a).
- **Frame**: The sampling window that travels through the original image is resized to the video dimensions and constitutes a frame of the generated video (see Figure 3-1 b). The video will show 25 frames per second.
- **Keyframe**: Frame of special interest where the camera movement is stopped. For example that frames corresponding to the ROIs' locations.
- **ROI or attention object**: Both terms are used sometimes indistinctively, although the definition of attention object denotes more information (minimum perceptible time and size, attention value, etc.). A ROI is the spatial region occupied by the attention object. In this text, both terms are used to designate the regions where most semantic information is concentrated in the image and where the sampling window has to centre to extract the keyframes (see Figure 3-1 a).



a) ROIs and sampling windows centered on the ROIs



b) Frames generated by resizing all the sampling windows to the video's dimensions. The frames shown are the keyframes corresponding to the ROIs

Figure 3-1: Examples for sampling windows, ROIs and frames on a picture

3.2 System overview

In this section a general block diagram (see Figure 3-2) of the ROIs2Video algorithm and an overall description of each point will be presented. The specific tasks to complete at each point will be detailed individually in future chapters.

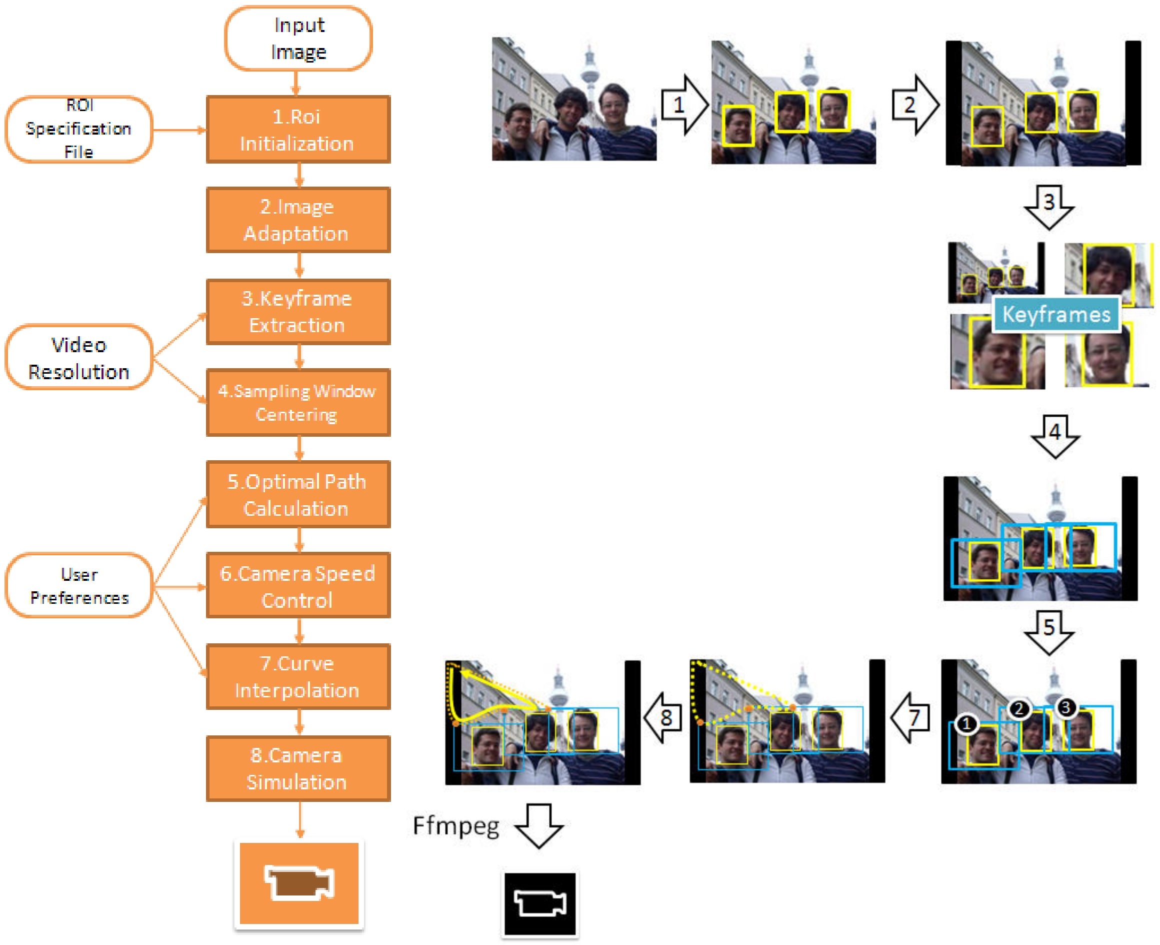


Figure 3-2: ROIs2Video algorithm steps.

1. **ROI initialization**: Read out the ROI descriptions from the specified file or create an automatic set of ROIs in case of generating a video preview of a photo.

2. **Image adaptation**: Read the input image and adapt it to the aspect ratio of the video dimensions. The ROIs may have to be relocated.

3. **Keyframe extraction**: Selection of the key positions for the sampling window.

4. **Sampling Window Centring**: Place the sampling windows trying to centre the ROIs.

5. **Optimal path calculation**: Apply sorting criteria to find a pleasant and coherent order for flying through the keyframes.

6. **Camera motion speed control**: Camera motion speed calculation based on the original image size, experimental observations and on the user's preferences.

7. **Curve interpolation**: Calculate an interpolated curve that joins the data points given by the keyframes and apply speed control to the curve.

8. **Camera simulation**: Travel the Catmull-Rom curve, saving the sampling windows as equally sized image files, which will constitute the frames of the video. The saved images will then be converted and coded to video with Ffmpeg libraries[4]. The video generation will allow certain flexibility in relation to the video characteristics, such as bitrate, codec or resolution.

3.3 Internal data structures

3.3.1 Image structure

The structure used for loading and dealing with an image is the *IplImage* structure, delivered in the OpenCV library and that presents following fields:

```
typedef struct _IplImage
{
    int  nSize;         /* sizeof(IplImage) */
    int  nChannels;     /* Most of OpenCV functions support 1,2,3 or 4
                           channels */
    int  depth;         /* pixel depth in bits: IPL_DEPTH_8U,
                           IPL_DEPTH_8S, IPL_DEPTH_16U,IPL_DEPTH_16S,
                           IPL_DEPTH_32S, IPL_DEPTH_32F and IPL_DEPTH_64F
                           are supported */
    int  dataOrder;     /* 0 - interleaved color channels,
                           1 - separate color channels.
                           cvCreateImage can only create interleaved
                           images */
```

[4] http://ffmpeg.mplayerhq.hu/

```
    int  origin;        /* 0 - top-left origin,
                           1 - bottom-left origin (Windows bitmaps style)
                           */
    int  width;         /* image width in pixels */
    int  height;        /* image height in pixels */
    int  imageSize;     /* image data size in bytes
                            (=image->height*image->widthStep
                            in case of interleaved data)*/
    char *imageData;    /* pointer to aligned image data */
    int  widthStep;     /* size of aligned image row in bytes */

}IplImage;

Note: Fields irrelevant for this work have been omitted for space reasons
```

3.3.2 ROI structure

The structure to manipulate ROI information will present the following fields:

```
typedef struct Roi{

      CvRect *rectangle;     //The rectangle representing the spatial
                                Location of the ROI
      CvPoint *ul_point;      /*The upper-left point of the sampling
                                window that centers the ROI*/
      CvPoint *lr_point;      /*The lower-right point of the sampling
                                window that centers the ROI*/
      int importance;        //Displaying-time factor

}Roi;
```

3.3.3 Trajectory structure

A variable of the type *Trayectory* will store the interpolated points that link one keyframe to the following one.

```
typedef struct Trayectory{

      int n;                     //Number of points in the array curve
      double ul_distance;        /*Distance the upper-left corner will
                                   travel in this trajectory*/
      double lr_distance;        /*Distance the lower-right corner will
                                   travel in this trajectory*/
      CvPoint *curve;            /*Array of interpolated points that
                                   conform a trajectory*/

} Trayectory;
```

3.4 ROI specification files

As already mentioned in chapter 2.3, the ROIs2Video application relies on the external image analysis and attention object model generation. This work is focused mainly on the video generation, independently on the semantic values of the regions of interest and therefore will define a structure for the ROI specification file, which has to be respected by any possible external detector. The file will be read out and stored into the ROI structures presented in 3.3.2. The file will be written in XML format, and will have to contain a numbered node <ROIx> for each ROI. Nested in the <ROIx> node, the information for the coordinates *(x,y)* for the upper-left corner, the width, height and the relevance of the ROI have to be found like shown in the following example

```
− <opencv_storage>
  − <ROI1>
      <x> 1 </x>
      <y> 2 </y>
      <width> 3 </width>
      <height> 4 </height>
      <importance> 1 </importance>
    </ROI1>
  − <ROI2>
      <x> 5 </x>
      <y> 6 </y>
      <width> 7 </width>
      <height> 8 </height>
      <importance> 1 </importance>
    </ROI2>
  − <ROI3>
      <x> 9 </x>
      <y> 10 </y>
      <width> 11 </width>
      <height> 12 </height>
      <importance> 1 </importance>
    </ROI3>
  </opencv_storage>
```

The meaning of the first four tokens (x, y, width, and height) is cleared in Figure 3-3.

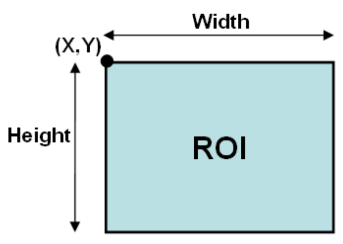


Figure 3-3: Specification of a ROI

The meaning of the Importance token is the importance of the ROI and will be explained later (see chapter 4.8).

The read-out of the xml file will be done using the available file storage functions in OpenCV. This is the reason why the root node obligatorily has to be tagged with <opencv_storage>.

Alternatively, if no ROIs want to be defined, the application has to present a mode that generates a basic video preview of the image. This mode will be detailed in chapter 4.1.2.

The XML file will not follow MPEG standards, because this would imply heavier labeling but could be desirable for a 100%MPEG compliant application.

3.5 Zooming and shrinking images

During the generation of the output video, it is necessary to oversample (zoom) or undersample (shrink) images, when adapting sampling windows to frames [16]. Zooming requires the creation and assignment of values to new pixels. The easiest and fastest method is the Nearest Neighbour interpolation, which tends to replicate the nearest pixel. A special case of the Nearest Neighbour interpolation is in fact the Pixel Replication, applicable when the size of an image wants to be increased an integer number of times. Each column is replicated *n* times and then each row is replicated *n* times. Although the method is fast, it produces pixelation (checkerboard effect) for high factors.

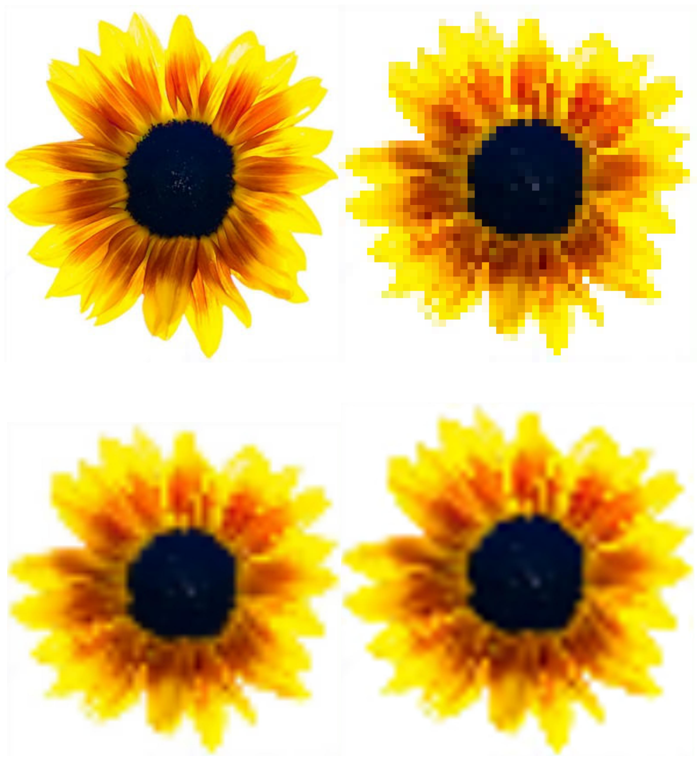


Figure 3-4: Comparison of the performance of the different interpolation methods. From left to right and up to down, we have the original image, the interpolated image using NN interpolation, using bilinear interpolation and bicubic interpolation. The images have been generated shrinking the original image to a resolution of 50x50 pixels and then zooming in to a resolution of 1200x1200.

A slightly more sophisticated way of zooming images is the bilinear interpolation, applied in the ROIs2Video tool, and which uses the average of the four nearest neighbours of a point.

Other interpolation methods, as for example the bicubic interpolation, use more neighbour points to obtain the interpolated value. This generally provides better and smoother results, but is also computationally more demanding. In the ROIs2Video application, it does not seem to be useful to apply a complex method and it is preferable to use the bilinear interpolation to reduce processing time.

The CvReference library (see Appendix D) in OpenCV includes the needed methods, so the digital image interpolation has not to be implemented from scratch.

4 Development

4.1 ROI initialization

4.1.1 ROI initialization from file

The first attempt of defining the ROI specification files was a simple text file, which contained each ROI specified in a separate line in the form

X_{ROI1} Y_{ROI1} $Width_{ROI1}$ $Height_{ROI1}$ $Relevance_{ROI1}$
X_{ROI2} Y_{ROI2} $Width_{ROI2}$ $Height_{ROI2}$ $Relevance_{ROI2}$
…

The final solution tries to take advantage of XML's robustness. The mandatory structure of the XML files was described in section 3.4. The read-out of these files is done using OpenCVs file storage functions, which provide a complete set of access functions to XML files. The following is an example of an actual XML file with two ROIs.

```
<?xml version="1.0"?>
<opencv_storage>
      <ROI1>
            <x> 988 </x>
            <y> 454 </y>
            <width> 347 </width>
            <height> 433 </height>
            <importance> 1 </importance>
      </ROI1>
      <ROI2>
            <x> 986 </x>
            <y> 961 </y>
            <width> 389 </width>
            <height> 569 </height>
            <importance> 1 </importance>
      </ROI2>
</opencv_storage>
```

When opening the XML file, OpenCV automatically controls the integrity of the XML file and checks that some necessary nodes are included. The XML files have to start with the declaration of the xml version and the root node has to be tagged as <opencv_storage>.

The next step is to read each ROI and insert it into a *CvSeq* sequence, where all the ROIs will be stored and returned. Each ROI is tagged with <ROIx>, where x is an increasing counter. The data of each ROI is retrieved in two steps:

1. The file node containing the requested data is found using the *cvGetFileNodeByName*, that returns the map of a particular node

2. The ROI data (x, y, width, height & importance) is extracted from the node using the specific read method (*cvReadIntByName* or *cvReadRealByName* depending on the case).

4.1.2 Automatic ROI initialization

In the particular case in which there are no ROIs associated to the original image, the ROIs2Video can generate a simple automatic division of the image. Currently, this process divides the image in 4 parts (see Figure 4-1) and generates a clockwise camera movement. This mode defines internally four dummy ROIs, positioned at *(1, 1), (w/2, 1), (1, h/2)* and *(w/2, h/2)*, where w is the image width and h the image height. The dummy ROIs have dimensions *w/2 x h/2*.

When running the ROIs2Video application in this mode no ROI sorting will be applied, because the order wants to be maintained as shown in Figure 4-1. Also the interpolated curves between ROIs will consist of straight lines and the curvature parameter (explained in chapter 4.7.2-Catmull-Rom interpolation), eventually selected by the user, will be ignored.

This option is a very first approximation to the generation of videos from images without a previous semantic analysis. This can be applied, for example, for image preview purposes.

Another possibility would be a zoom-in into the centre of the image, assuming the major part of the information is confined in the centre.

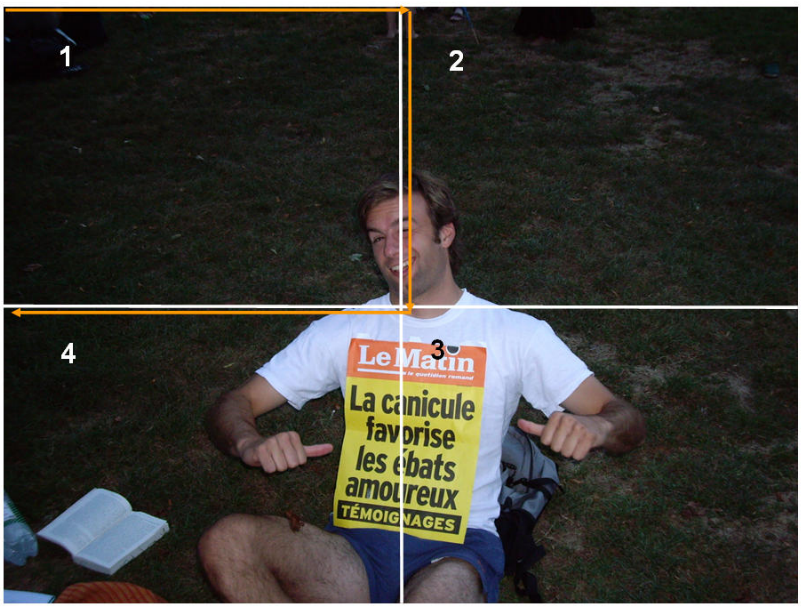


Figure 4-1: Clockwise automatic video generation without specification of ROIs

4.2 Aspect ratio adaptation of the images

The resolution of the output video (i.e. width x height pixels) is user configurable: the user can choose the resolution of the video according to the display size of his device. It should be noticed, that if the selected video resolution and the original image do not have the same aspect ratio, it is necessary to adapt the image to the screen by adding black horizontal or vertical bars. When adding the bars, the positions of the ROIs have to be adequately displaced the same number of pixels of the black bars' size.

The size in pixels of each black bar is calculated

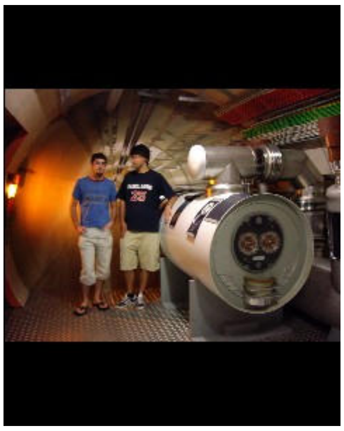
- in case of upper and lower bars as:

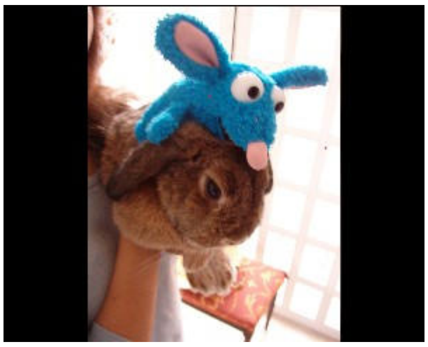
$$h_{bar} = \frac{\left(w_{image} \times \frac{h_{video}}{w_{video}} \right) - h_{image}}{2}$$

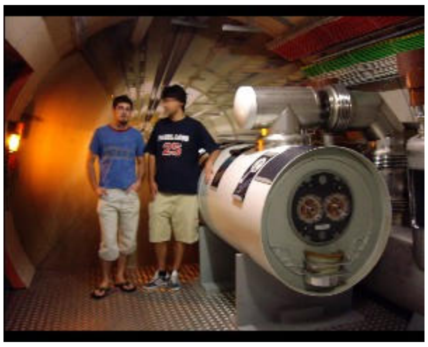
- in case of left and right bars as:

$$w_{bar} = \frac{\left(h_{image} \times \frac{w_{video}}{h_{video}} \right) - w_{image}}{2}$$

Adding the bars can be more or less noticeable, depending on the aspect ratios of the video and the image. The worst case is when a horizontal/vertical image wants to be transmoded to a vertical/horizontal video (see Figure 4-2). Though, the decision of adding bars produces less side-effects than other adaptation solutions, and what is more important, avoids information loss.


a) Image dimensions: 2304 x 1728
Video dimensions: 240 x 300


b) Image dimensions: 1232 x 1632
Video dimensions: 300 x 240


c) Image dimensions: 2304 x 1728
Video dimensions: 300 x 240

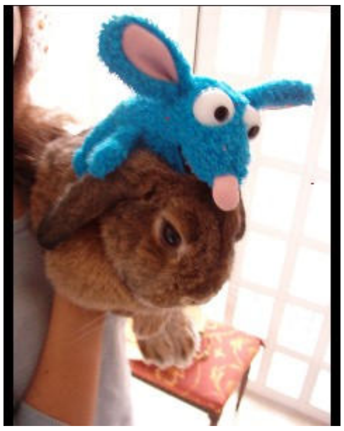

d) Image dimensions: 1232 x 1632
Video dimensions: 300 x 240

Figure 4-2: Examples for the aspect ratio adaptation in bad cases (a&b) and in better cases (c&d)

Other solutions to the problem of adapting the image to the output display resolution and their inconvenients are:

- **Image cropping**: This solution involves the elimination of possible important areas of the image which is a weak point of this kind of adaptation, especially in the worst case mentioned before.
- **Aspect ratio change**: This solution results in a distorted image which, depending on the amount of change, can be unpleasant for the viewer. This is the default solution when using OpenCV, because the interpolation methods in the mentioned library automatically change the aspect ratio of the image if it is resized to a different aspect ratio.
- **Image flipping**: In addition to cropping or adding black bars, the image could be previously rotated in order to reduce the effect of cropping or black bars. This step supposes that the display can also be rotated, what is not true for every device (for example if the video wants to be viewed on a personal computer). The action of flipping the image was actually implemented, but finally eliminated because it seemed unpleasant when viewing the videos on fixed screens. Also, if a video is generated by the camera fly-through of various input images, it would be annoying to have to turn the display every time the image is flipped.

4.3 Finding the optimal browsing path

4.3.1 Jumping to the nearest unvisited ROI

The first attempt to establish the order of presentation of the ROIs was to start by the ROI situated most to the left and then continue jumping to the closest, still not displayed ROI and so on. For a very reduced number of ROIs (<5), or specific cases where the ROIs where placed following certain patterns (for example all ROIs placed in a row), this method showed up coherent browsing paths. However, when the number of ROIs increased, this fairly simple algorithm reduced drastically the quality of the browsing paths, returning chaotic browsing paths with back and forth movements. The solution of finding a good browsing path had to be found in some other way.

4.3.2 Simulated Annealing

The optimal browsing path will be obtained using a *Simulated Annealing* [17] approach, which will return a sorted array of ROIs with a path-distance near to the optimum. The algorithm imitates the process of metallurgic cooling of a material to increase the size of its crystals and reduce their defects. This technique is often used to solve the Travelling Salesman Problem[5] finding a good path for the salesman, who wishes to visit a certain set of cities travelling the shortest distance possible. If the number of cities to travel is big, this problem can not be solved by brute force in an affordable amount of time.

Simulated annealing usually locates a good approximation to the global optimum of the browsing path. Each step in the simulated annealing process replaces the actual solution by a random nearby solution (i.e. exchanging two nodes of the browsing path). If the new solution has a lower cost, it is chosen; if the new solution shows up to have a worse cost, it can be chosen with a probability that depends on the worsening and on the 'temperature' parameter, that is gradually decreased during the process imitating the cooling process of metals. At the beginning of the process, when the temperature is high, more changes will be admitted, while worse changes will be admitted more seldom when the temperature is cold at the end of the process. The allowance for "uphill" moves saves the method from becoming stuck at local minima.

As the trained eye might have noticed, it is important to define the appropriate cooling ratio. If we define a high rate of temperature decrease, the algorithm will take less time, but probably will find a relatively bad solution. On the other hand, a very slow cooling schedule will find solutions near to the optimal with higher probability, but will take more processing time. Therefore it is

[5] http://www.tsp.gatech.edu

http://en.wikipedia.org/wiki/Simulated_annealing necessary to find a compromise between computing time and the actual quality of the solution. In our particular case, the path has to be as short as possible, because a longer path will mean less comfort in the viewing of the output video, as the simulated camera will move back and forth through a strange path.

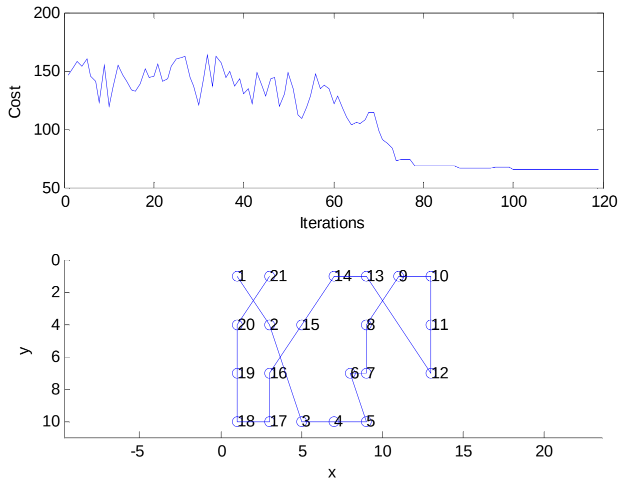
The simulated annealing algorithm has a strong random character, marked by:

- The initial random path.
- The defined exchange function, which in our particular implementation exchanges fortuitously two nodes of the path.
- The acceptation function for unfavourable exchanges.

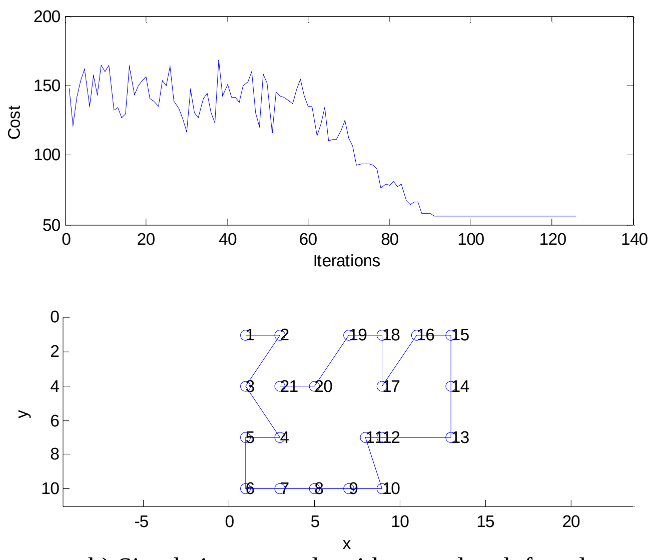
This random character has as a consequence that two executions of the same data set will most probably have different solutions, especially when the set of data points grows. The actual quality of the solutions is hard to predict.

This approach works much better than elementary browsing path generations (for example our first implementation of jumping to the next unvisited ROI) and generally shows good results, especially in pictures that contain a moderate number of ROIs (<15). For pictures with many attention objects (e.g. group photos), the path generated by this algorithm is acceptable in most of the cases, but sometimes it could be improved.

Figure 4-3 shows two different simulations of camera path generation with the Simulated Annealing algorithm using the same parameters. Each one shows a plot of the cost function evolution along the iterations and a plot of the obtained path through all the cities (in this case the ROIs) showing the random character of this algorithm.



a) Simulation example with a relatively bad path found



b) Simulation example with a good path found

Figure 4-3: Two simulation examples of the Simulated Annealing with a random set of data points

The advantages a good browsing path shows up are:

- ☑ Shorter and therefore smaller sized videos.
- ☑ Reduction of the processing time to generate the video.
- ☑ More pleasant video watching sensations as a short browsing path will implicitly reduce the number of camera zigzag movements.

The pseudocode of the simulated annealing algorithm looks as follows:

```
Initialize i0, c0, L0;
k=0;
i=i0;
repeat
        for l=1 to Lk
                generate j∈S
                if f(j)<=f(i) ➔ i=j;
                else if exp((f(i)-f(j))/ck)>rand[0,1] ➔ i=j;
        k=k+1;

        ck=ck x α

until final condition;

i: actual browsing path
j: possible next browsing path
ck: temperature variable
c0: initial temperature
Lk: iterations in each step
f(i): cost function of path i
α: cooling parameter (0.8<α<0.99999)
```

4.4 Keyframe extraction

The specified ROIs, or the image divisions in the video without semantic analysis, act as video keyframes. Additionally, the full image will be added as a keyframe at the beginning and at the end of the video in order to give an initial and final overview of the complete image and let the viewer locate every object. The detailed steps are as follows:

- The video will start off with the full image (first keyframe) and will zoom in towards the first ROI. This pattern is called *forward sentence* [3].
- Following the obtained browsing path, the video will show consecutively the different defined ROIs, connecting them through Catmull-Rom interpolation curves (shifting mode). The dimensions of the sampling window on the picture will vary and adapt to the size of the displayed ROI. The captured picture will be converted into the video-sized frame using bilinear interpolation. Bilinear interpolation is used instead of other more elaborate interpolations (as for example bicubic interpolation) because it requires less processing time and delivers good enough results for a video where each frame is displayed 40ms and where the human eye's limitations won't allow to distinguish so fine details.
- After having travelled through all the ROIs, the virtual camera will zoom out and show the complete image again (last keyframe). This pattern is called the *backward sentence* [3].

The forward and backward sentence patterns form together the *ring sentence* [3]. Using the ring sentence, the viewer of the video perceives a general overview of where every element is situated in the image, before and after the virtual camera zooms in to offer a detailed view. Figure 4-4 shows the keyframes associated to a particular image.

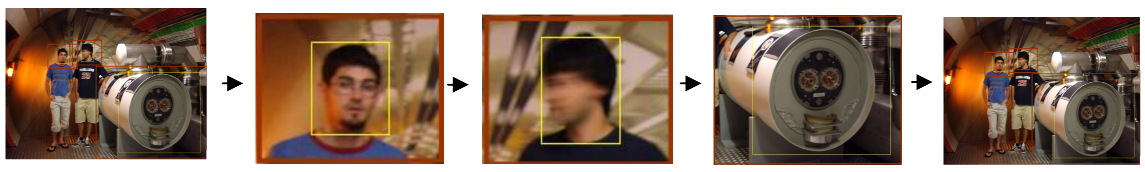


Figure 4-4: Examples of keyframes in a ROIs2video sequence

4.5 Sampling window centering

As explained before, the keyframes of the video will be constituted by the complete image followed by the set of regions of interest. The ROIs will be centred perfectly in the sampling window. Other similar Image2Video applications [1] centre faces on the upper third portion of the window, stating that the body below the face attracts the user's attention. In our case the specific type of each ROI is not defined, as the implementation is independent of the ROI types, and therefore this kind of case is not taken into account. Exceptionally, when the ROI is next to an image border, the window can't centre the attention object and will be situated at the border(s) of the image.

When centring the ROI in the sampling window, it is necessary to decide:

- How to show objects of a size bigger than the display size (in pixels).
- Up to which zooming factor small attention objects will be shown in the video (see section 2.1.2for 'minimal perceptible size' concept definition).

In the first implementation of the Image2Video CAT, the video displays the defined ROIs in their original size if the ROI's size is smaller than the output video resolution (spatial scale 1:1) or in the biggest possible size if the ROIs' dimensions are greater than the output video resolution, obtaining a ROI which occupies the whole video screen.

In the actual version, the user can set the maximal zooming factor he wants to apply to small ROIs. This way, the presentation size of a ROI is limited either by the maximal zooming factor or by the video resolution. When setting the zooming factor, the user has to be aware that if the ROI is zoomed in excessively, the corresponding frames generated through bilinear interpolation will lose resolution and quality. It will be left to the user to establish his preferences and taste. Another approach could be to group close ROIs and show them together.

Large ROIs are reduced in order to fit into the sampling window. Further investigation could examine the possibility of splitting large ROIs and travelling through them without reducing.the ROIs resolution.

4.6 Base speed calculation

The motion speed of the camera is given by the distance (measured in pixels on the original image) jumped from one frame to the next one. Therefore the curve defining the position of the upper-left corner of the sampling window (which guides the movement of the sampling window as will be seen in the next section) will contain an array of points each one separated a particular pixel distance from its neighbours and thus characterizing the movement's speed pattern.

It must be realized that a displacement of *i* pixels is not the same in pictures of different resolution. Figure 4-5 shows a possible case, where a camera panning movement (movement in the xy plane) between to ROIs is simulated in two different size versions of the same image.

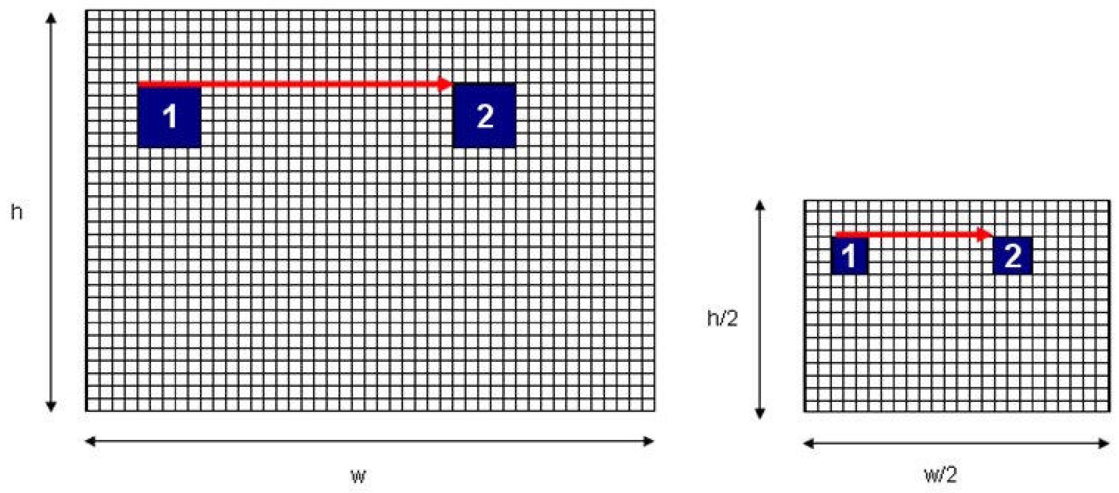


Figure 4-5: Pixel distance between ROIs in different size pictures.

In this case, the camera would take double time to simulate the panning motion in the bigger image, because the distance between the attention objects is double as long. In order to solve this problem, a base speed, which has been experimentally found to be adequate with a certain resolution (2816x2112 pixels corresponding to a picture taken with a standard 6 megapixel camera in full resolution), has been selected. For pictures with different resolutions, the pixel jump is modified proportionally. If the viewer prefers faster or slower camera movement, a speed factor which will multiply the predefined pixel jump has been introduced and can be modified to obtain different speed outputs. By selecting a faster or slower camera movement, the user is also having influence on the computing time of the program. Faster camera movements will need less intermediate image files written to hard disk and less image resizings and therefore finally will have a shorter processing duration as a consequence.

The default defined jump is 8 pixels for images with dimensions 2816x2112. For a picture of 1408x1056 pixels, the jump would be rounded to 4 pixels. This pixel distance jumped from frame to frame on the original image is called the base speed and has floating point precision.

4.7 Path interpolation for the simulated camera movement

For delivering the simulated camera movement, it is necessary to specify the exact path, which gets defined by the interpolation of the *data or control points* given by the ROIs. The data points will be the upper-left corners of the sampling windows centred at the ROIs and thus the interpolation of new points will also be for the upper-left corners of the sampling window (the lower-right corner of the sampling window can move “freely” to allow increasing and decreasing for simulating zooming as discussed later in 4.7.2.)

Interpolation (unlike approximation) is a specific case of curve fitting, in which the function must go exactly through the data points. Through interpolation we are able to obtain new points between the control data.

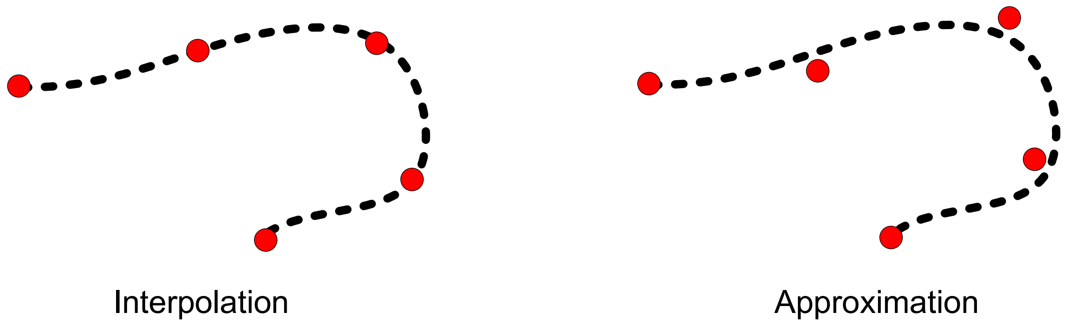


Figure 4-6: Interpolation and approximation

4.7.1 Linear interpolation

The most simple and direct interpolation is the linear interpolation[6], which was applied in the first implementation of the Image2Video CAT being then substituted by the Catmull-Rom interpolation method [18]. Linear interpolation is given by the following equation for two data points (x_a, y_a) and (x_b, y_b):

$$y = y_a + \frac{(x - x_a)(y_b - y_a)}{(x_b - x_a)}$$

This is the first interpolation one would possibly think of, as it is easy to implement, but it is generally not a good solution for the camera simulation movement. Linear interpolation is not differentiable (has no tangential continuity) at the control points and therefore the movement is abrupt and unpleasant for the viewer.

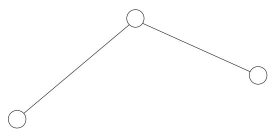


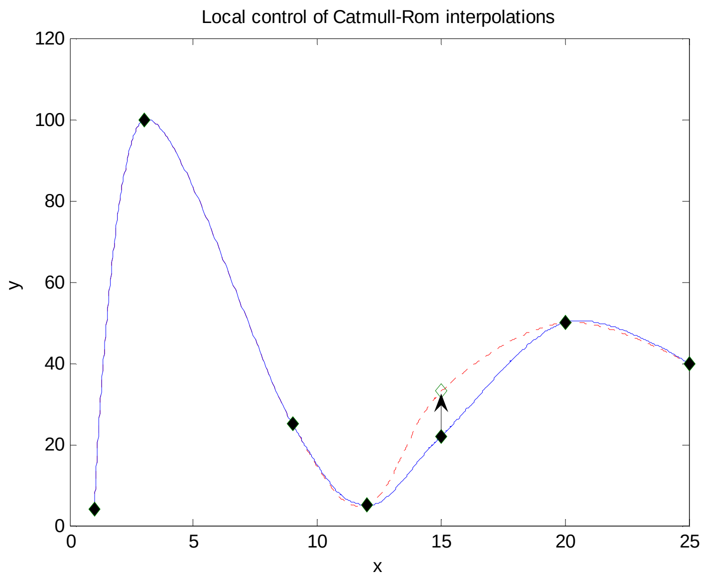
Figure 4-7: Positional, but not tangential continuity at the central data point when using linear interpolation

[6] http://en.wikipedia.org/wiki/Linear_interpolation

4.7.2 Catmull-Rom interpolation[7]

A more elaborate interpolation, often used in different kinds of motion simulation, is the Catmull-Rom interpolation [18] [19], named after its developers Edwin Catmull and Raphie Rom. Even though it is often called the Catmull-Rom spline, it is not really a spline (smooth, piecewise, polynomial curve approximation), because it does not verify the C^2 property (its second derivative is not continuous). Instead, it imposes derivative restrictions at the control points. Some of the features of the Catmull-Rom interpolation are:

- C^1 continuity
- The specified curve will pass through all of the control points (what is not true for all types of splines). This is desirable for our application, as we want to centre the camera precisely on the regions of interest, although a small error could be acceptable.
- The specified curve is local, i.e. moving one control point affects only the interpolated points in a limited bound region and not all the points. This is not really important for our tool, as we are dealing with static images converted automatically into video without user interaction, but would be desirable if for example the user could stop the video and change the order of the control points or change the regions of interest.



[7] Information about interpolation can be found under the following links:

http://arantxa.ii.uam.es/~pedro/graficos/teoria/

http://jungle.cpsc.ucalgary.ca/587/pdf/5-interpolation.pdf

http://www.cs.cmu.edu/~fp/courses/graphics/asst5/catmullRom.pdf

Figure 4-8: Local control – Moving one control point only changes the curve over a finite bound region

- The curvature of the interpolation is easily modifiable through a single parameter *c*, which means the user can select if he wants a strongly curved interpolation or prefers a more straightened interpolation between the control points (see Figure 4-9).

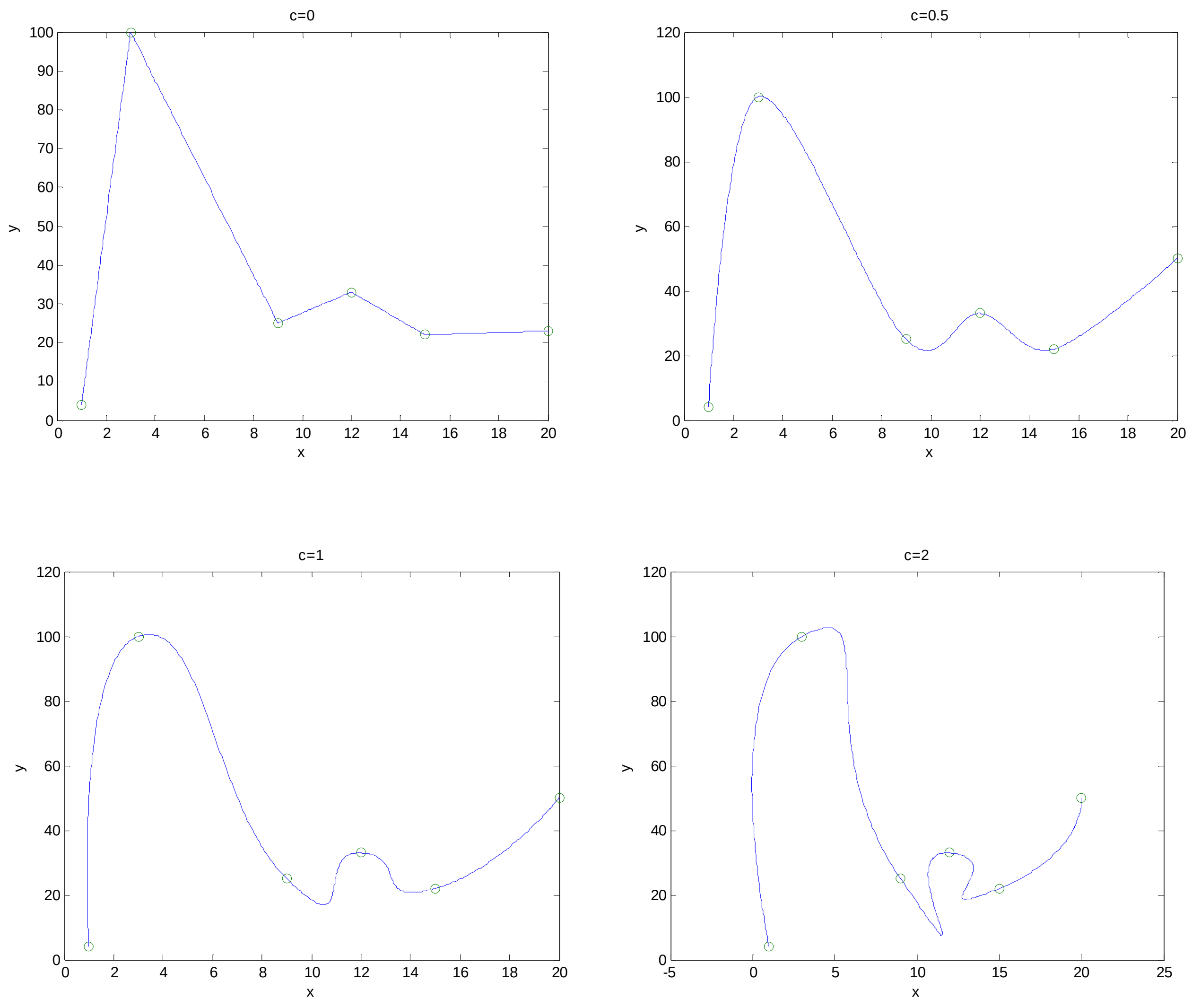


Figure 4-9: The effect of c. Example of browsing paths with different curvature values (from straight to exaggerated interpolations), all done with Catmull-Rom interpolations.

The Catmull-Rom interpolations are easily implemented through its geometry matrix

$$p(t)=\begin{bmatrix}1 & t & t^2 & t^3\end{bmatrix}\begin{bmatrix}0 & 1 & 0 & 0\\ -c & 0 & c & 0\\ 2c & c-3 & 3-2c & -c\\ -c & 2-c & c-2 & c\end{bmatrix}\begin{bmatrix}p_{i-2}\\ p_{i-1}\\ p_i\\ p_{i+1}\end{bmatrix}$$

that can be traduced into the following pseudocode:

```
%First we prepare the tangents
For each data_point i
     If the data point is the first or last of the array
            m1[i]=0 ;
            m2[i]=0 ;
     Else
            m1[i]=c*(data[i+1].y-data[i-1].y) ;
            m2[i]=c*(data[i+1].x-data[i-1].x) ;

%Now we calculate the interpolated points between the data points
For each data_point i
      j=0 ;
      For t=0; t<1; t=t+τ
            h00=2·t^3-3·t^2+1;
            h01=-2·t^3+3·t^2;
            h10=t^3-2·t^2+t;
            h11=t^3-t^2;
            interpolated_data[j].y=h00*data[i].y+h10*m1[i]+
                                   h01*data[i+1].y+h11*m1[i+1];
            interpolated_data[j].x=h00*data[i].x+h10*m1[i]+
                                   h01*data[i+1].x+h11*m1[i+1];
            j++;
```

Even if the loop increases t linearly in steps of τ (see previous pseudocode), the resulting interpolated data is not equally separated. A camera travelling through this trajectory will not move at constant speed. Thus, the following step is to reparameterize the obtained interpolated data so the camera moving through it has the desired speed function.

4.7.3 Arc-length reparameterization

A simple way to reparameterize the data is the arc-length reparameterization, which precomputes a table of values by running a standard Catmull-Rom interpolation with unevenly separated data. The number of entries in the table will depend on the needed precision in the arc-length calculations. The arc-length is the distance of the path walked over the interpolated curve points. It is approximated through the distance travelled over the straight lines joining the interpolated points and is therefore a good approximation if the interpolated points have a high density on the curve (see Figure 4-10).

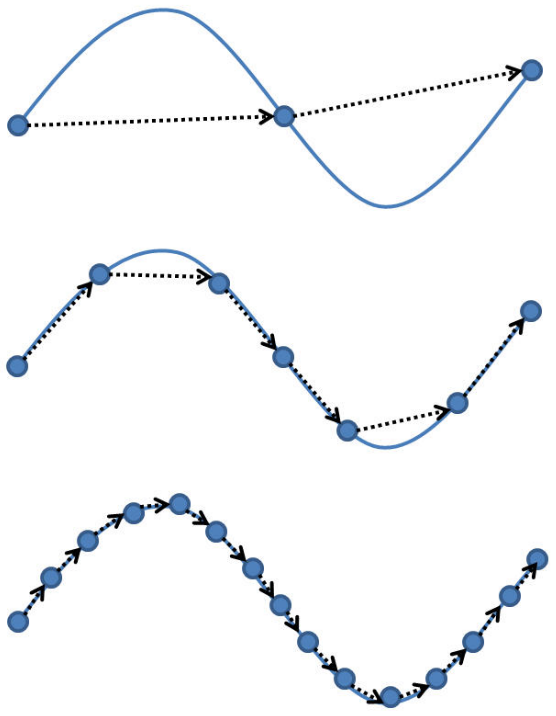


Figure 4-10: Arc-length approximations with increasing precision.

With the help of the precomputed table, it is possible to find a point at a given arc length distance, and therefore it is feasible to find the interpolation points compliant with a particular speed function.

Index	T	Arc-length
0	0.00	0.00
1	0.05	0.08
2	0.10	0.15
3	0.15	0.39
4	0.20	0.66
…	…	…
20	1.00	3.58

Table 1: Arc-length table for reparameterization

Using the table, it will be necessary to loop increasingly the distance L according to the speed function and use it to compute the according value of the parameter *t* using the next formulas[8].

$$aux = \frac{L - ArcLength[index]}{ArcLength[index+1] - ArcLength[index]}$$

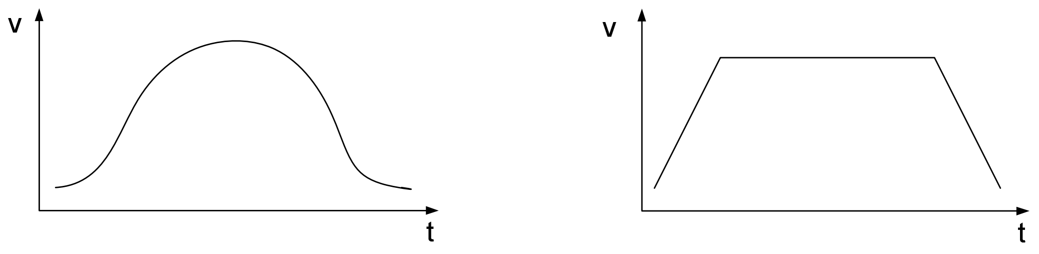
$$t = t[index] + aux \cdot (t[index+1] - t[index])$$

[8] http://jungle.cpsc.ucalgary.ca/587/pdf/5-interpolation.pdf

```
%Reusing the m1 and m2 variables obtained in Catmull-Rom
For each data_point i
      calculate number of points to calculate n;
      L=0;
      For j=0; j<n; j++

            L+=step; %Step can be constant or variable according to
                     %the desired speed function

            find L's index in the precalculated table;

            calculate t according to the recently stated formulas;

            $h00=2\cdot t^3-3\cdot t^2+1$; %Exactly as in normal Catmull-Rom
            $h01=-2\cdot t^3+3\cdot t^2$;
            $h10=t^3-2\cdot t^2+t$;
            $h11=t^3-t^2$;
            interpolated_data[j].y=h00*data[i].y+h10*m1[i]+
                                   h01*data[i+1].y+h11*m1[i+1];
            interpolated_data[j].x=h00*data[i].x+h10*m1[i]+
                                   h01*data[i+1].x+h11*m1[i+1];
```

4.7.4 Speed control

Speed control is applied to determine the precise camera speed along the trajectory. Real camera motion will normally include ease-in and ease-out, that is, the camera will move slower at the beginning and at the end of the trajectory. To include the ease-in and ease-out effects, the step distance on L is not constant and has to be calculated according to some speed function, as shown in Figure 4-11.



a. Smooth ease-in&ease-out

b. Parabolice ease-in &ease-out with constant acceleration

Figure 4-11: Typical speed functions for ease-in&ease-out camera movement.

In the present ROIs2Video application the broken line speed function (see Figure 4-11 b), has been chosen for simulating a real camera motion. There is no special need to complicate the speed control function, as the eye will notice no difference and this alternative is sufficiently good.

If the user prefers the camera to move at constant speed without ease-in and ease-out, he has the possibility of selecting this option when running the program. This option is useful for example when generating dummy ROIs automatically, as the camera won't stop at the keyframes and it has no sense to slow down the camera speed.

4.7.5 Zoom control

An additional fact to consider is when movement between two ROIs, that require differently sized sampling windows and thus zoom factor change along the trajectory as shown in Figure 4-12.

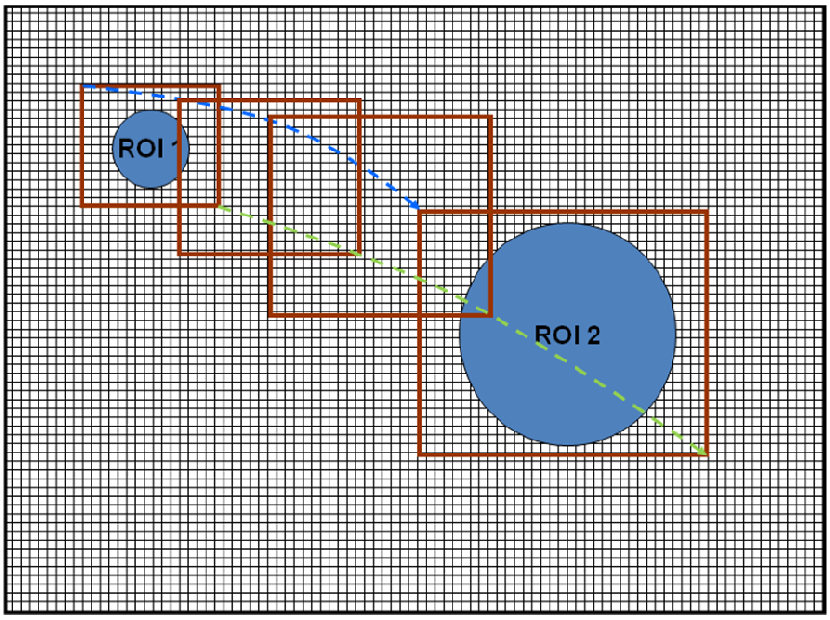


Figure 4-12: Path between ROIs involving zoom factor change.

As told before, the upper-left corner of the sampling window follows the interpolated curve, while the lower-right corner of the sampling window will implicitly follow a different trajectory in order to achieve the simulation of zooming. The curve for the lower-right corner is not precalculated, but is computed "in real-time" for each sampling window taking into account the actual point of the upper-left corner and that the window is increasing or decreasing also with parabolic ease-in and ease-out (Figure 4-11b) between two keyframes.

In these cases with zoom factor change, the pixel jump calculated (remember the base speed calculation in chapter 4.6) is assigned to the curve of the corner that scans the longest distance by reducing when necessary the pixel distance when interpolating the Catmull-Rom curve of the upper-left corner. The distances to be covered by each corner are roughly approximated by the straight line junction between each two points, so the actual jump differs from the ideal one. This error in the speed is not noticeable.

This pixel distance adjustment is essential for the smoothness of the video and is a way of controlling the zooming speed without having to set up an additional function. Otherwise, in cases of two close ROIs with noticeable different sizes, the viewer would note an explosive growth of the sampling window, which is not desirable at all.

4.7.6 Overview of the interpolated Catmull-Rom curve

Summarizing, the interpolated curve is done in two steps:

1. Standard Catmull-Rom interpolation, using the pseudocode in 4.7.2 and obtaining a curve with points with different separations.
2. Arc-length reparameterization of the interpolated curve, considering
    a. Constant speed or ease-in&ease-out speed control as described above
    b. The maximal separation between data points, in order to control the zooming speed, as

$$d' = d \cdot \min\left\langle 1, \frac{D_{ul}}{D_{lr}} \right\rangle$$

D_{ul}: distance travelled by the upper-left corner

D_{lr}: distance travelled by the lower-right corner

d: desired pixel-distance jumped from frame to frame

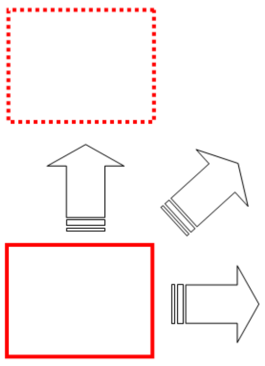
d’: pixel-distance jumped from frame to frame by the upper-left corner so the fastest of both corners travels at d pixels/frame

4.8 Camera simulation

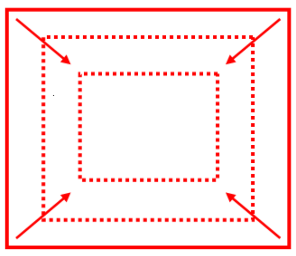
The virtual camera used to generate the videos from static images has been provided with panning and zooming movements.

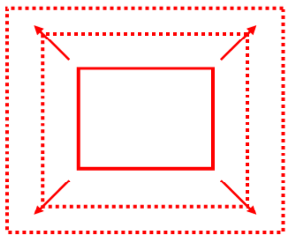
- Panning is defined as the two-dimensional movement of the camera in the x and y axis, without allowing movement in the z axis - Figure 4-13(a)-
- Zooming is defined as the action of approaching to or moving away from the image by moving in the z axis, without allowing movement in the x and y axis -Figure 4-13 (b),(c)-

The system is able to pan and zoom simultaneously (Figure 4-13(d)). The only movement, the camera is not able to fulfil is rotation. Rotation would require additional external annotation, but could be desirable for example in cases where an angled text was wanted to be viewed horizontal.

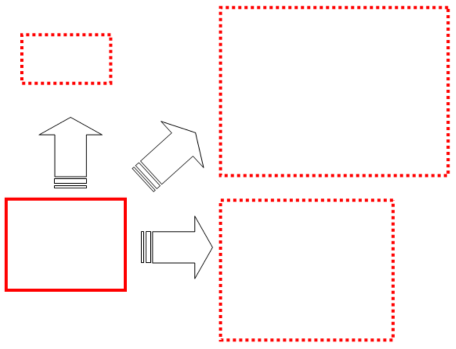


a) Pan





b) Zoom in **c) Zoom out**



d) Combined pan and zoom

Figure 4-13: Some examples for the defined camera movement

The whole path the virtual camera follows during the entire video is divided into trajectories. Each trajectory starts and ends with a ROI or the whole image in the first and last route. For its movements, the virtual camera needs the information about the starting and ending window dimensions of each trajectory, as well as the Catmull-Rom curve that joins both sampling windows. The virtual camera will stop at each interpolation point of the curve, copy the pixels inside the sampling window, resize the copied pixels through bilinear interpolation to obtain a frame and store the frame as an image file in a specific temporary folder. These temporary images can be converted afterwards into a video externally using ffmpeg. The image files are stored in JPEG format, although they could be written to the hard drive in all the formats allowed by OpenCV's libraries. The files will be named increasingly, starting at 0000.jpg, so maximally 10.000 files can be stored. This number is more than sufficient for the video generated from a single image, where normally an amount around a thousand files is written (500 for smaller images up to about 1500 for high resolution images). The process of writing the temporary files to disk is a bottleneck to the application's performance and slows down significantly the speed of the video generation. The solution to this problem, which is out of the scope of the project, would be to code the video file inside the application and disassociate the ROIs2Video program from the Ffmpeg libraries. This way all the data would be processed in RAM memory and no temporary files would have to be written on hard disk.

The size of the sampling window, that the virtual camera is capturing, grows or decreases linearly between the two ends of the route.

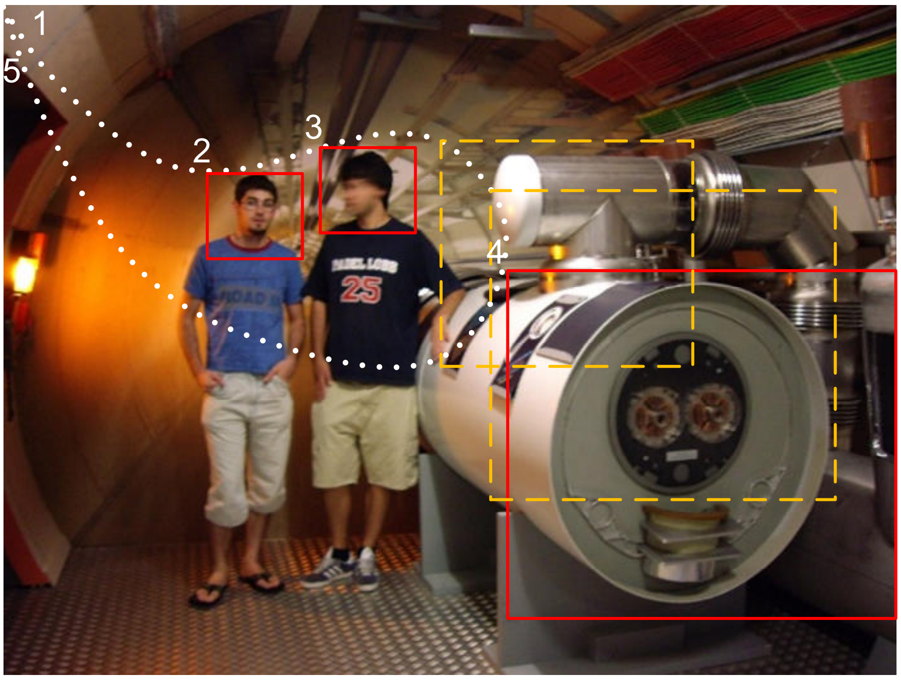


Figure 4-14: Scheme of the camera simulation.

Figure 4-14 shows a scheme of the camera simulation showing size variations of the selections on the original image. The red sampling windows determine the keyframes, i.e. ROI positions, while the orange dashed line shows an example of two intermediate frames in which the size of the sampling window increases towards the value of the last ROI sampling window. The complete camera path is composed of the following routes:

- 1→2: Panning+zooming from the whole image to the first ROI (Forward sentence)
- 2→3: Panning between two ROIs that are captured by equally sized sampling windows
- 3→4: Panning+zooming between two ROIs that require sampling windows with different sizes
- 4→5: Panning+zooming from the last ROI to the whole image (Backward sentence)

According to the Minimal Perceptible Time –MPT- concept (chapter 2.1.2), it would be desirable if the camera stopped at the end of each route to be able to see the ROIs in detail. Liu et al. state in [9] that the MPT of a face is about 200ms and that the MPT of a text is 250ms for each word. As our Image2Video CAT is aimed to be used for any type of object, we will let the external ROI descriptor decide the relevance of the attention object. A standard stop of 8frames/25fps=320ms is set at each object and the external ROI detector will be responsible for giving a relevance factor for the object. The time stopped at each attention object will be calculated as the product of the standard stop multiplied by the relevance factor. For example, for a relevance factor set to 2, the camera movement will stop at this object 2*320ms=640ms. In the opposite case, for an absolutely non-relevant object, the importance factor can be set to 0 and the camera movement will pass through this object without stopping. However, if the speed control is set to ease-in and ease-out, the camera will move slower when passing through the ROI, even if it has zero relevance. If the relevance of each attention object is not defined, it will be considered as 1.

4.9 Video coding from the temporal image files

The last step is to generate a proper video file from the temporal image files that were saved on the hard drive. The video coding is done using the Ffmpeg libraries (see Appendix E for more information). The generated video file can use various video codecs and bitrates, which have to be specified when invocating the ROIs2Video program. The generated temporal files are deleted before leaving the program.

5 Integration and testing

5.1 Integration of the modules

The lifecycle of the application has followed a protoyped development. In the first phase of the project a very simple and rather limited ROIs2Video application was developed and afterwards the single modules where improved and generated individually. The change history of each module of the ROIs2Video is summed up in Table 2.

Module	Changes
ROI initialization	At the beginning, the ROIs were not read out from a file, but generated by OpenCV's face detector. As the results of the detector did not satisfy the expectations, it was changed to manual file annotation and file read out. The possibility of autogenerating a set of ROIs was added afterwards, answering to the existing demand in the aceMedia project.
Image adaptation	At the very first moment, there was no image adaptation, as the video resolution was fixed and the user could not change it. In the next step, the user was able to decide the video resolution, but really there was no image adaptation and the user had to generate videos in a similar aspect ratio as the image, in order to not distort the full image on the video. If the selected video aspect ratio was different from the image aspect ratio, the image would be distorted changing its aspect ratio in order to fit into the video screen. A new attempt considered that the images had basically only two aspect ratios, a vertical of approximately w/h=3/4 and a horizontal of approximately w/h=4/3, what is true for most standard images taken with digital cameras. The video also had to be generated with one of both aspect ratios and, in the case the video had the opposite aspect ratio than the image, the image would be flipped 90 degrees. This case was wrong for two reasons: the screen displaying the video also had to be turnable and the adaptation did not consider all the cases where the image or the video didn't have the expected aspect ratios. The final decision was to add the black bars, as explained in chapter 4.2.

Keyframe extraction	The keyframe extraction started considering only the ROIs, without generating the ring sentence, because the camera movement did not consider zooming and was only able to pan through the image.
Sampling Window Centring	No remarkable changes made in this module.
Optimal path calculation	The optimal path was not calculated at the beginning of the execution, but at the moment the camera arrived at a ROI the nearest unvisited ROI was chosen. For implementing the Simulated Annealing, first a model was programmed in Matlab to probe if the method was really valid. Besides the distance, other cost functions have been tried out using the Matlab model, obtaining worse results. For example the sum of the turned angles or combinations of the sum of angles and the travelled distance has been tried out as cost functions.
Camera motion speed control	The first approximation set the pixel jump on the input image between frames as a constant value and it had to be modified manually for each execution, trying out values for the different image resolutions. The experimental observations led to the final decision of establishing a standard velocity that adapts automatically to each resolution and leaving open the possibility for the user of selecting a faster or slower camera motion.
Curve interpolation	The curve interpolation passed from linear to Catmull-Rom interpolation. Catmull-Rom interpolation was chosen after comparing it with other interpolating methods and searching a compromise between simplicity and quality of the interpolated data. The Catmull-Rom interpolation was first simulated in Matlab due to inexperience in the field of curve interpolation and because the results were rather unknown and had to be tested on a simple interpreter before programming the algorithms in C. The next step was to reparameterize the data. For reparameterizing the data and before having found information about the arc-length reparameterization, a more simple method was used: generating much denser curves than needed and discarding all the useless points. This was unefficient

	and therefore the final solution with arc-length reparameterization was implemented.
Camera simulation	In first place the simple panning of a camera was programmed. The panning function initially only needed the origin and destination points, without having to specify the linear trajectory. Based on this function, the zooming and panning function was programmed. When the curve interpolation was done through Catmull-Rom, the zooming and panning function had to be changed and receive the curve the upper-left corner of the sampling window travelled.

Table 2: Development of the modules

As stated in the table, some of the final modules were developed initially on Matlab for trying out the results, due to inexperience in the fields. When these modules were found to be correct and showed up the expected functioning, they were reprogrammed in C and finally integrated with the rest of the code. These modules were principally the Simulated Annealing sorting module and the Catmull-Rom interpolation.

5.2 CAIN Integration

This section will explain the integration of the Image2Video in the CAIN framework as a new CAT [20]. In order to integrate the Image2Video in the CAIN, it is necessary to change the ROIs2Video application and convert it to the obligatory structure of a CAT so it can be added to the existing architecture. The result of a CAT creation is a *.jar* file which includes a group of files needed for the execution of the adaptation tool. The needed files are:

- ☑ A mandatory Java class file[9] with the code to perform the adaptation (Image2VideoCAT.class).
- ☑ A mandatory XML file with the description of the adaptation capabilities of the CAT (Image2VideoCAT.xml CAT Capabilities Descriptor file).
- ☑ Optional files included in the .jar file which could be Java libraries, native libraries or any other resource file needed for the CAT's execution. In the case of the Image2Video application, it is necessary to include:

[9] All the mandatory files must have the name of the CAT with varying file extensions, for example in the present case the files Image2VideoCAT.class and Image2VideoCAT.xml have to be packed in a file named Image2VideoCAT.jar

- The *OpenCV* -Open Computer Vision- library (for a detailed description please read Appendix D): Because it is not desirable to depend on any externally installed version of the library and to avoid incompatibilities of OpenCV version changes in the CAIN.

- A shared library generated from the native C code of the ROIs2Video application with some slight changes of the interface and the necessary adaptations to work with JNI.

Additionally the *ffmpeg* program, used initially as an external program and invocated before as a system command, has now to be used through the *ffmpegJNI CAT* already included in the CAIN framework.

5.2.1 Mandatory Java class file: Image2VideoCAT.class

The Java interface has to include a *Image2VideoCAT.class* file that extends the class *CATImplementations* and implements its *adapt* method, needed for the integration of every CAT.

```
public abstract MediaContentList adapt(MediaContentList inputContent,
MediaFormatType outputFormat, String outputFolder, Properties
properties);
```

To have an overview, the Java *adapt* method carries out the actions seen in Figure 5-1:

1. Before calling the native routines to generate the video, it is necessary to check if the temporal folder exists and has any temporary files left over from previous erroneous executions. In case the folder exists, any files in it will be deleted. On the contrary, if the folder does not exist, it is created. The temporal folder can’t be created anywhere in the file tree, because it could interfere with files from other programs or CATs. It is created inside the folder where the CAIN uncompresses the *.jar* package. The path to this folder has to be transmitted to the native program.

2. The native ROIs2Video application is called. This step results in the generation of the temporal images (the videoframes) that are left in the folder created in step 1.

3. The videoframes are converted to a video file using the ffmpegJNI CAT.

4. The temporal folder is cleaned and removed.

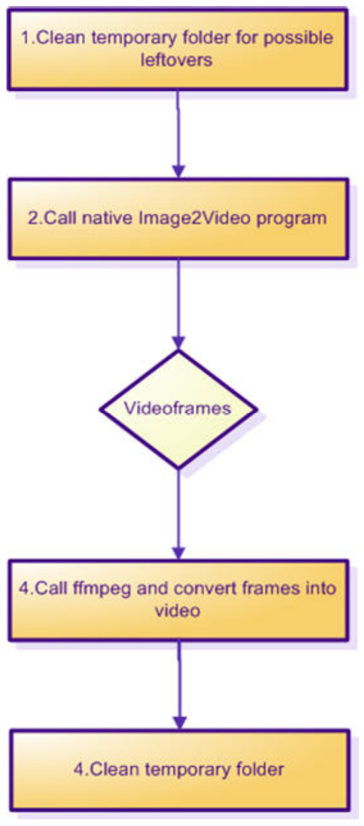
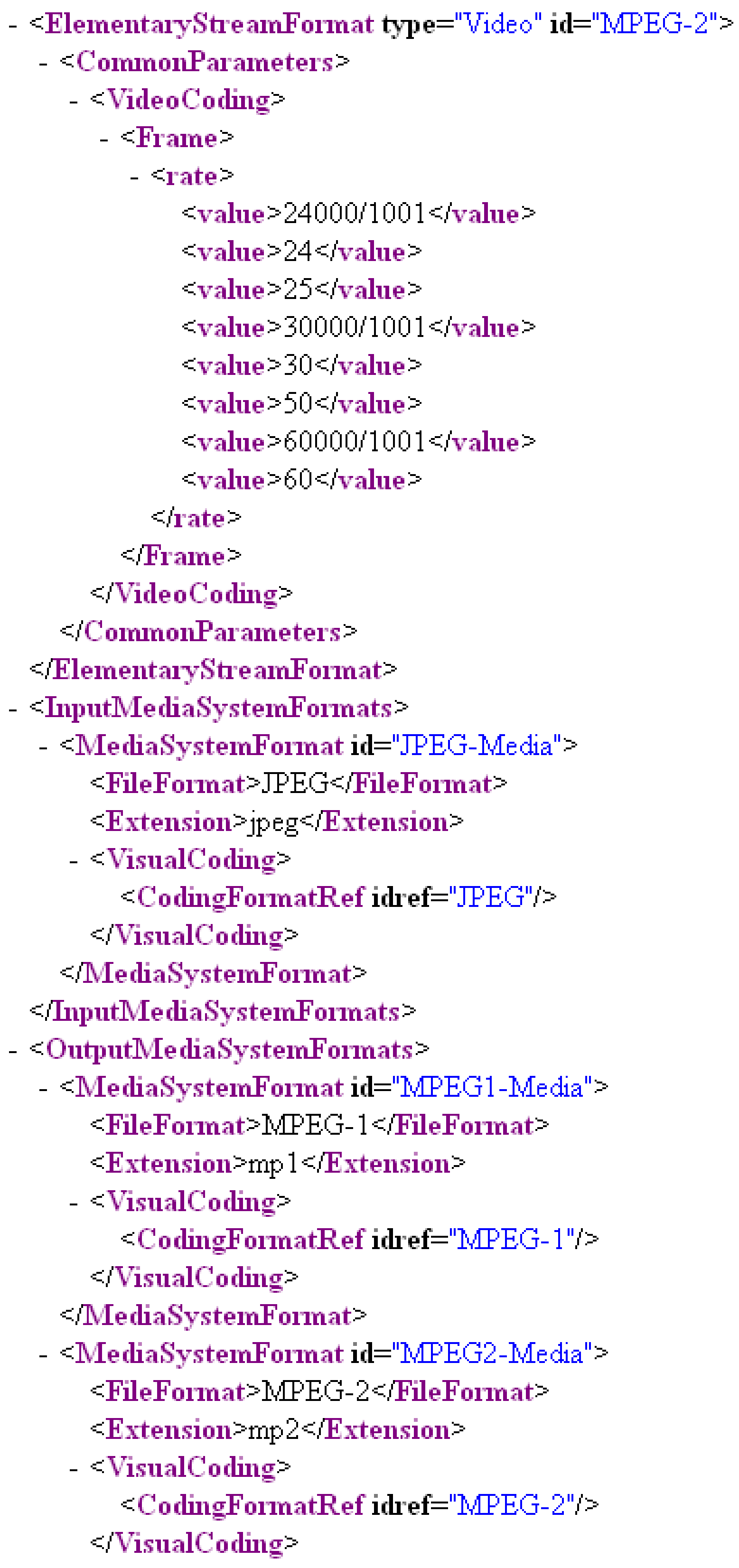

1.Clean temporary folder for possible leftovers
2.Call native Image2Video program
Videoframes
4.Call ffmpeg and convert frames into video
4.Clean temporary folder

Figure 5-1: Image2Video CAT operation

5.2.2 Mandatory XML description file: Image2VideoCAT.xml

The XML description file states the actions the corresponding CAT fulfils. In our case, the shown Image2VideoCAT.xml file informs CAIN's decision module that the input file has to be a JPEG image file with resolutions between 500x500 and 3000x3000 pixels and that a MPEG-1/2 video will result as an output.

```
- <cat xsi:schemaLocation="acemedia:cme:cat file:./CATCapabilities.xsd">
    <name>Image2VideoCAT</name>
    <description>Generates a video passing through an image's ROIs</description>
  - <!--
     JPEG visual elementary stream adapation capabilities description
    -->
  - <ElementaryStreamFormat type="Image" id="JPEG">
    - <CommonParameters>
      - <VisualCoding>
        - <Frame>
          - <height>
            - <range>
                <from>500</from>
                <to>3000</to>
              </range>
            </height>
          - <width>
            - <range>
                <from>500</from>
                <to>3000</to>
              </range>
            </width>
          </Frame>
        </VisualCoding>
      </CommonParameters>
    </ElementaryStreamFormat>
  - <ElementaryStreamFormat type="Video" id="MPEG-1">
    - <CommonParameters>
      - <VideoCoding>
        - <Frame>
          - <rate>
              <value>25</value>
              <value>30</value>
            </rate>
          </Frame>
        </VideoCoding>
      </CommonParameters>
    </ElementaryStreamFormat>
```



```
- <ElementaryStreamFormat type="Video" id="MPEG-2">
  - <CommonParameters>
    - <VideoCoding>
      - <Frame>
        - <rate>
            <value>24000/1001</value>
            <value>24</value>
            <value>25</value>
            <value>30000/1001</value>
            <value>30</value>
            <value>50</value>
            <value>60000/1001</value>
            <value>60</value>
          </rate>
        </Frame>
      </VideoCoding>
    </CommonParameters>
  </ElementaryStreamFormat>
- <InputMediaSystemFormats>
  - <MediaSystemFormat id="JPEG-Media">
      <FileFormat>JPEG</FileFormat>
      <Extension>jpeg</Extension>
    - <VisualCoding>
        <CodingFormatRef idref="JPEG"/>
      </VisualCoding>
    </MediaSystemFormat>
  </InputMediaSystemFormats>
- <OutputMediaSystemFormats>
  - <MediaSystemFormat id="MPEG1-Media">
      <FileFormat>MPEG-1</FileFormat>
      <Extension>mp1</Extension>
    - <VisualCoding>
        <CodingFormatRef idref="MPEG-1"/>
      </VisualCoding>
    </MediaSystemFormat>
  - <MediaSystemFormat id="MPEG2-Media">
      <FileFormat>MPEG-2</FileFormat>
      <Extension>mp2</Extension>
    - <VisualCoding>
        <CodingFormatRef idref="MPEG-2"/>
      </VisualCoding>
      </MediaSystemFormat>
    </OutputMediaSystemFormats>
  - <AdaptationModalities>
    - <AdaptationModality>
      - <Mode href="acemedia:cme:cat:cs:Image2Video-CAT-Modes">
          <Name>Keyframe Replication Sumarization</Name>
        </Mode>
        <MediaSystemRefInput idref="JPEG-Media"/>
        <MediaSystemRefOutput idref="MPEG1-Media"/>
        <MediaSystemRefOutput idref="MPEG2-Media"/>
      </AdaptationModality>
    </AdaptationModalities>
</cat>
```

5.2.3 Adaptation of the native C code

The native C code has to be modified, so it doesn't work as a standalone program and can be called as a function from a Java program. Therefore, the prior main routine is converted to a function receiving the indispensable parameters from the Java Image2VideoCAT class using JNI – Java Native Interface-. The main function is renamed to the *generateVideo* function with the following header:

```
JNIEXPORT jint JNICALL Java Image2VideoCAT_generateVideo(JNIEnv* jEnv,
jobject jObj, jobjectArray jArray, jstring path)
```

The *jobjectArray jArray* is the variable where the arguments are passed to the native function. It will contain an array of Java Strings, that are converted in the *generateVideo* routine fictitiously to the *int argc* and *char** argv* variables, that were used in the prior main function. This way no other changes have to be done in the original code. On the other hand, the *jstring path* contains the path to the temporal folder.

5.2.4 Modification of the Ffmpeg library

During the standalone development of the ROIs2Video tool, the Ffmpeg library collection is ran through a system command, assuming the Ffmpeg software is installed on the machine and having installed the latest subversion of the software. Contrary, for the integration of the Image2Video tool in CAIN, the ffmpegJNI CAT is used to reduce the risk of incompatibilities and external dependencies on programs which may not be installed. During the change between both Ffmpeg versions, some problems occurred, because the ffmpegJNI CAT is built on an older version of the internal libraries and does only support the video generation from image files with dimensions divisible through sixteen (though the video file does not have this restriction). A little patch had to be introduced, to generate the image files respecting the restriction, but generating afterwards the video file with the correct dimensions.

5.3 Testing

5.3.1 Testing environment specifications

The system has been tested on different computers, using Microsoft Windows and Linux operative systems (the versions for Windows and Linux are slightly different).

The used computer specifications are:

Computer	Processor	RAM	Hard disk
Home computer 1	Intel Pentium D 2.8 GHz	1 GB	250 GB
Home computer 2	Intel Pentium Mobile 1.8 GHz	384 MB	40 GB
Lab computer 1	Intel Pentium 4 3.2 GHz	1 GB	100 GB for Windows 50 GB for Linux
Lab computer 2 (Laptop)	Intel Pentium 4 Centrino 1.86 GHz	2GB	50 GB for Windows 30 GB for Linux

Table 3: Computer specifications

The application has been tested on Microsoft Windows XP SP2 (Home computer 1&2 and Lab computer 1) and on Linux Ubuntu 6.10 (Lab computer 1). Also, during the integration in the aceMedia CAIN framework, the system was tested on Linux CentOS 4.5 (Lab computer 2).

5.3.2 Library versions

The libraries used during the development of the applications have been:

Library	Version
Ffmpeg	• libavutil version: 49.0.0 • libavcodec version: 51.9.0 • libavformat version: 50.4.0 Built on Jun 20 2006 02:00:39, gcc: 4.0.3
	• libavutil version: 49.0.0 • libavcodec version: 51.11.0 • libavformat version: 50.5.0 Built on Sep 20 2006 00:26:15, gcc: 4.1.2 20060906 (prerelease) (Ubuntu 4.1.1-13ubuntu2)
	• libavcodec version: 47.23 • libavformat version: 46.16 Built on Mar 31 2005 11:37:24, gcc: 3.3.4 (Debian 1:3.3.4-13) (This older version corresponds to the FfmpegJNI CAT)
OpenCV	OpenCV RC1 Released August 11, 2006

Table 4: Library versions

5.3.3 Test examples

The tests have been done with a set of different images, taken from personal images, from the aceMedia database and from the Internet, considering

- different resolutions
- number of ROIs
- disposition of ROIs
- relative size of ROIs

In the tests, the videos have been generated using the different execution parameters (camera speed, curvature in the Catmull-Rom curvatures, automatic ROI generation…). Some execution results of the program are compared in Table 5.

	File	Image resolution	Video resolution	Number of ROIs	Speed factor	Number of frames	Execution time
1	tenis.jpg	600x435	320x240	7	4	315	**5.28s**
2	tenis.jpg	600x435	150x100	7	1	1259	**8.39s**
3	2+torre.JPG	2112x2816	320x240	3	4	337	**54.88s**
4	2+torre.JPG	2112x2816	240x320	3	4	387	**37.15s**
5	7.JPG	2816x2112	320x240	7	4	400	**33.66s**
6	19.jpg	1600x1064	240x320	19	4	840	**25.29s**
7	19.jpg	1600x1064	240x320	19	1	1582	**61.33s**

Table 5: Execution results running the ROIs2Video application under Linux on Lab computer 1

It can be observed how the execution time is longer:

- for higher resolution images – compare for example execution 1 with execution 3
- for the same image with a slower speed factor - for example execution 6 against execution 7
- not necessarily if the image contains more ROIs than another with the same resolution. (It depends on the distribution of the ROIs in the image.)
- if the image has been adapted to the video aspect ratio, because the black bars increase the size of the image

A set of example output videos can be found following the URL:

http://www-gti.ii.uam.es/publications/image2video.

6 Conclusions and future work

6.1 Conclusions

The developed system has generally reached its goals, offering smooth camera simulation for most of the images. Camera motion is improved significantly when reparameterizing the Catmul-Rom interpolation and adding ease-in and ease-out at the beginning and between two ROIs.

It is important to mention that the application shows better video results (smoother motion) when using higher resolution images as input. On the one hand, the system has been designed and tested mostly for pictures with decent resolution. On the other hand it has less use to transmode pictures with very poor resolutions, as they can be visualized directly on a small display.

Videos with dimensions close to the image resolution show particularly bad results, as the sampling window is confined to an area not much bigger than itself and is not able to move freely. In these cases, the sampling window will be centred with a high probability exactly on the same position for more than one ROI and there will be no panning between ROIs, what can lead to confusion(see Figure 6-1).

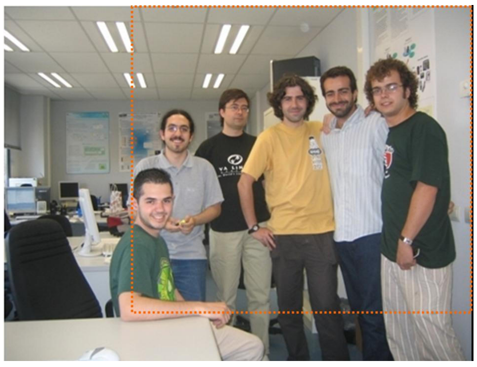


Figure 6-1: The same sampling windows centres the three faces situated at the right part of the image.

The profit of the transmoding is optimized for high resolution pictures and for video dimensions inferior than the image resolution. It can be said that for these cases the Image2Video transmoding offers a really visual attractive solution.

6.2 Future work

To continue the present work and improve the performance of the ROIs2Video application, further investigation could be applied to certain points:

1. As mentioned before, due to the dependance on Ffmpeg, it is necessary to write/read a high number of temporal images to/from hard disk, which slows down significantly the

performance of the application. The video-coding could be incorporated to the system so all the data is kept in RAM.

2. The high number of image resizings also takes in account a considerable amount of time. Future investigation could investigate in how to optimize the resizing of the images.

3. Other sorting algorithms and cost functions could be tried out, although the results reached with Simulated Annealing and the distance cost function are in most cases very acceptable.

   The quality of the browsing path is mostly subjective, but it could be tried to find an objective measure of the quality of a path (for example number of crossings in the browsing path) and repeat the Simulated Annealing process if the quality is not high enough. Another option would be to repeat the Simulated Annealing process several times and pick the solution with the best cost.

4. The major drawback of applying the distance cost function relies in the fact, that the cost function is not influenced by the zoom factor of the ROIs and it is generally not pleasant if the virtual camera is continuously zooming strongly in and out.

5. Future work could include some improvement in displaying large ROIs that don't fit in the sampling window. A possibility would be to split those ROIs and scan each ROI with spatial resolution 1:1 or similar. Some scanning paths are more evident than others as can be seen in Figure 6-2, where the scanning path to the right is questionable and should be compared with other options.

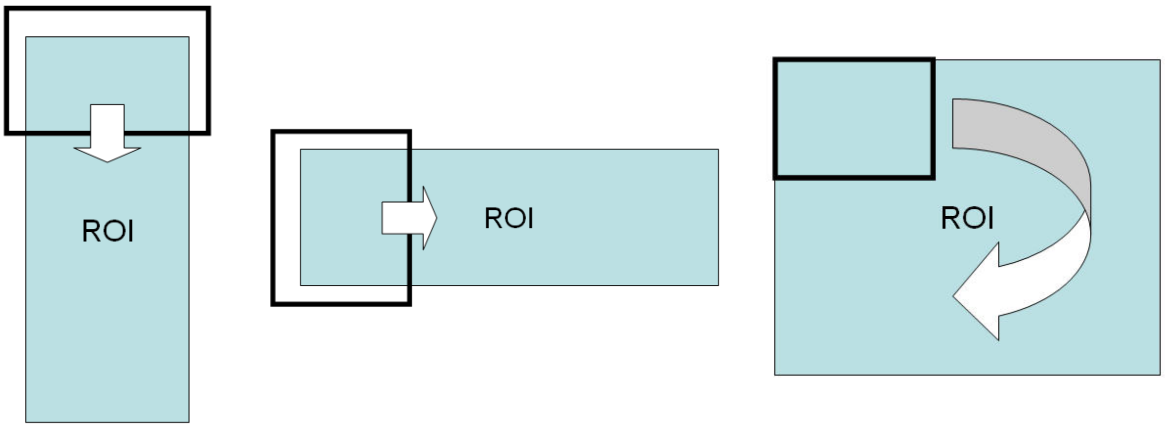


Figure 6-2: Scanning paths for splitted ROIs. The rectangle with bold strokes represents the sampling window.

6. Using additional annotation and allowing the ROIs to be rotated rectangles, the simulated camera movement could be improved adding the capability or rotating on the xy-plane. As mentioned before, this would be useful for example for reading rotated texts more easily.

6 Conclusiones y trabajo futuro

6.1 Conclusiones

Se puede decir que la aplicación desarrollada ha alcanzado sus objetivos principales de ofrecer una simulación de movimiento de cámara agradable y suave para la mayor parte de imágenes. El movimiento de cámara se ha visto mejorado significativamente con la introducción de la interpolación Catmull-Rom reparametrizada con aceleración al inicio y frenada al final de cada unión entre ROIs.

Es importante mencionar que la aplicación muestra mejores resultados (movimientos de cámara más agradables) cuando las imágenes de entrada son de alta resolución. Por una parte, el sistema se ha diseñado y probado mayoritariamente con imágenes de resoluciones medias y altas. Por otra parte tiene poco sentido convertir imágenes de baja resolución a vídeo, ya que estas tienen poca finura de detalle y se pueden ver directamente en una pantalla pequeña.

Vídeos con resolución cercana a la resolución de la imagen muestran particularmente malos resultados, ya que la ventana de muestreo no tiene apenas margen para moverse libremente. En estos casos con mucha probabilidad la ventana de muestreo coincidirá exactamente para más de una ROI y no habrá panning entre dichas ROIs, lo que puede llevar a confusión del usuario (ver Figure 6-1).

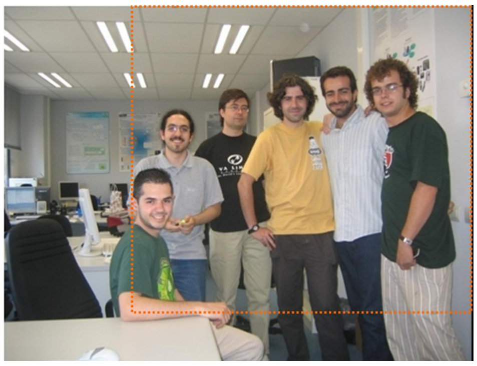


Figure 6-1: La misma ventana de muestreo centra las tres caras de las personas situadas en la parte derecha de la imagen.

El mayor beneficio de la conversión de imágenes a vídeo se obtiene usando como entrada una imagen de resolución decente y generando un vídeo de resolución claramente inferior. Para estas imágenes la adaptación Image2Video ofrece una solución realmente atractiva para el espectador.

6.2 Trabajo futuro

Para proseguir el trabajo presente y mejorar el funcionamiento de la aplicación ROIs2Video, la investigación futura podría centrarse en los siguientes puntos:

1. Como se mencionó anteriormente, debido a la dependencia de la librería Ffmpeg, es necesario escribir y leer una gran cantidad de imágenes a/de disco, lo cual frena significativamente el rendimiento del programa. La codificación de vídeo debería incorporarse al sistema, de forma que los datos no saliesen de la memoria RAM.

2. El alto número de redimensionamientos de imágenes también supone una ralentización del proceso. Investigación futura podría abarcar la optimización de estos redimensionamientos.

3. Podrían probarse otros algoritmos y funciones de coste, aunque generalmente los resultados del algoritmo de Simulated Annealing con función de coste de distancia son satisfactorios.

   La calidad de la ordenación de presentación de las ROIs es en mayor parte subjetiva, pero se podría intentar hallar una medida de calidad objetiva y repetir el algoritmo de Simulated Annealing si la calidad de la ordenación no es lo suficientemente alta. Otra opción sería repetir la ordenación Simulated Annealing varias veces y elegir la solución con menor coste.

4. El mayor inconveniente de aplicar una función de coste por distancia está en el hecho de que la función de coste no está influenciada por el factor de zoom de cada ROI y generalmente no es agradable si la cámara está acercándose y alejándose continuamente.

5. Trabajo futuro podría mejorar la presentación de ROIs grandes que no caben en la ventana de muestreo. Una posibilidad sería dividir dichas ROIs y escanearlas con resolución espacial 1:1 o similar. Unos caminos de escaneado son más evidentes que otros, como se puede ver en la figura 6-1, donde el camino de la derecha es uno de varios posibles y debería ser comparado con otras opciones.

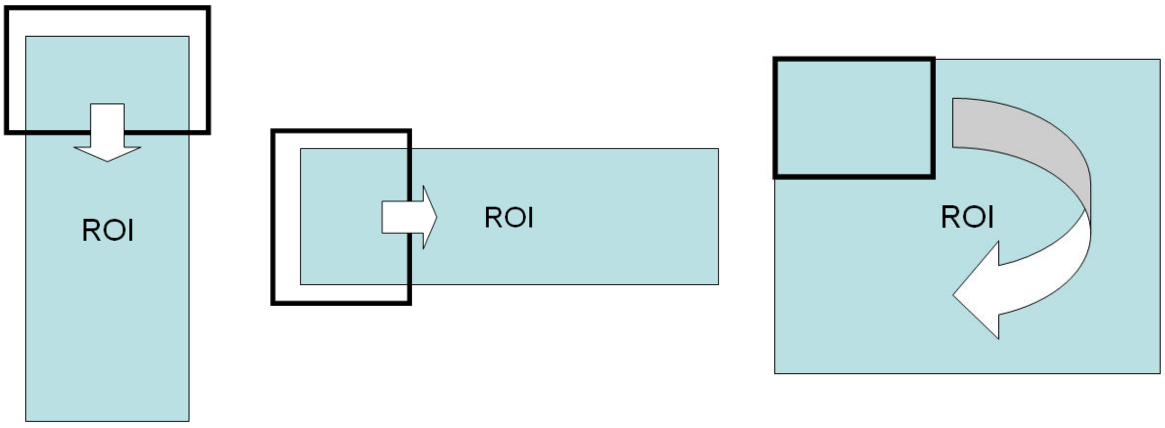


Figure 6-2: Caminos de escaneado de ROIs subdivididas. El rectángulo negro de trazado ancho representa la ventana de muestreo.

6. Usando anotación adicional y permitiendo que las ROIs sean rectángulos rotados, el movimiento de cámara simulado podría ser mejorado añadiendo la posibilidad de rotación en el plano xy. Como se mencionó anteriormente en el capítulo 4.8, esto sería útil por ejemplo para leer con mayor facilidad texto rotado.

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Glossary

JNI	Java Native Interface
ROI	Region Of Interest
CAT	Content Adaptation Tool
CAIN	Content Adaptation Integrator
CME	Cross Media Engine
PDA	Personal Digital Assistant
GUI	Graphical Use Interface

Appendices

A Running the application

The invocation parameters of the application are divided in two parts. In first place, it is possible to specify the desired execution options, by adding tag-value pairs. The possible tags are:

Video parameters

- '-b' Bitrate of the generated video. Reasonable bounds for the video bitrate are 100 (very low) to 99999 (very high).
- '-cod' Video codec to be applied in the video coding. Some example codecs that can be specified using the following strings are: 'mpeg1video', 'mpeg2video', 'mpeg4', 'wmv1'...
- '-w' Video width. It has to be bound between 1 and the image width, although values close to the limits are not practical.
- '-h' Video height. It has to be bound between 1 and the image height, although values close to the limits are not practical.

General parameters

- '-c' Catmull-Rom curvature parameter. Its bounds are 0 (linear interpolation) to 1(very curved interpolation). (Explained in chapter 4.7.2.)
- '-v' Speed multiplying factor. Any positive floating point value. (Explained in chapter 4.6)
- '-z' Maximal zoom applied on ROIs. Any positive floating point value. The ROIs will be zoomed in with a factor limited by the minimum permitted by the video resolution and the maximal zoom. (Explained in chapter 4.4)
- '-s' Flag to specify whether Simulated Annealing is applied (1) or not (0). Only the Boolean values 0/FALSE and 1/TRUE are allowed.
- '-a' Flag to specify whether the ROIs are read out from a file (0) or generated automatically (1), dividing the image in four ROIs and traveling clockwise through them (Explained in chapter 4.1). Only the Boolean values 0/FALSE and 1/TRUE are allowed.

It is not mandatory to specify all the values, because the parameters that are not manually specified will be set to default average or most generally used values.

In second place, and necessarily after the tag-value pairs, it is obligatory to specify the image files and, when needed, the files with the ROI information. In the case the ROIs want to be generated automatically (‘-a 1’), a sequence of the image paths has to follow the tag-value pairs. The generated video will contain the camera fly-through for all the images sequentially. Contrary, if the ROIs are specified in files (‘-a 0’ or ‘-a’ was not specified), one ROI file per image, a sequence of image path + ROI path pairs has to be specified. If the ‘–a’ tag was not indicated,

Some execution examples, supposing the executable file is named Image2Video, are:

- Execution specifying the bitrate, video dimensions, a codec and two images with the corresponding ROI files

```
>> Image2Video -b 5000 -w 400 -h 200 -cod wmv1 image1.jpg rois1.txt
image2.bmp rois2.txt
```

- Execution specifying video dimensions and generating the ROIs automatically

```
>> Image2Video -w 400 -h 200 -a 1 image1.jpg image2.bmp image3.jpg
```

- Wrong execution of the last example, because the order of the tag-value pairs and the image paths are inverted

```
>> Image2Video image1.jpg image2.bmp image3.jpg -w 400 -h 200 -a 1
```

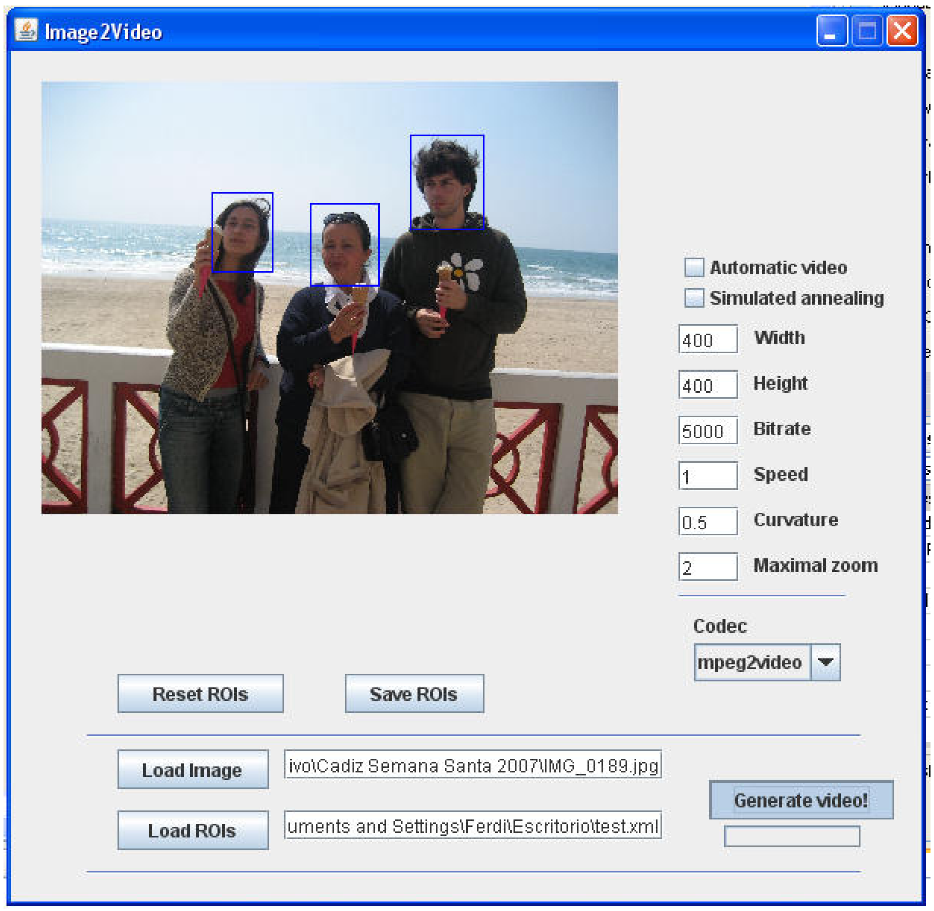
- Wrong execution, if the option ‘-a 1’ is activated, it is incorrect to specify ROI files

```
>> Image2Video –a 1 image1.jpg rois1.txt image2.bmp rois2.txt
```

B Manual ROI annotation tool

The graphical user interface, developed in Java using Swing classes, has been built for demo purposes and allows drawing the ROIs on the image and generating automatically the file containing the ROI specifications. If the ROIs want to be loaded from a file it is also possible. The GUI is a first version and can clearly be improved. Some of its limitations are:

- The execution finishes after generating a video and has to be run again for generating another video
- It generates only videos using a single image
- If a ROI has been drawn incorrectly it is impossible to correct it, only the possibility of starting drawing all the ROIs again exists.



Automatic video
Simulated annealing
400 Width
400 Height
5000 Bitrate
1 Speed
0.5 Curvature
2 Maximal zoom
mpeg2video
ivo\Cadiz Semana Santa 2007\IMG_0189.jpg
uments and Settings\Ferdi\Escritorio\test.xml

Figure B-1: Appearance of the Graphical User Interface

To generate a video using the GUI the order for proceeding is:

1. Load an image clicking on “Load Image”. The image will appear on the GUI

2. Draw the ROIs on the image. If the user committed a mistake, he can delete all the ROIs clicking on “Reset ROIs”. When finished defining the ROIs, the user has to click the “Save ROIs” button.

3. Alternatively, if the ROIs are already specified in a file, the user can load these clicking on “Load ROIs”.

4. At any moment, the user can change the parameter settings on the right side of the window.

5. The last step, when everything is correct, is to click the “Generate video!” button and the video will be generated.

C CAIN system overview [21]

C.1. Architecture

CAIN – Content Adaptation Integrator – is a multimedia adaptation engine integrating complementary adaptation approaches into a single module. Its main target is to adapt content in the most efficient way, searching a compromise between the computational cost, the quality of the final adapted media and the constraints imposed by the media formats.

As can be seen in Figure C-1, CAIN is divided in three main modules: the Decision Module (DM), the Execution Module (EM) and the battery of CATs available. Additionally, a set of support modules are necessary (e.g. MPEG-7/21 XML parsers).

The battery of CATs consists of four categories:

- Transcoder CATs
- Scalable Content CATs
- Real-time content driven CATs
- Transmoding CATs (e.g. The Image2Video application)

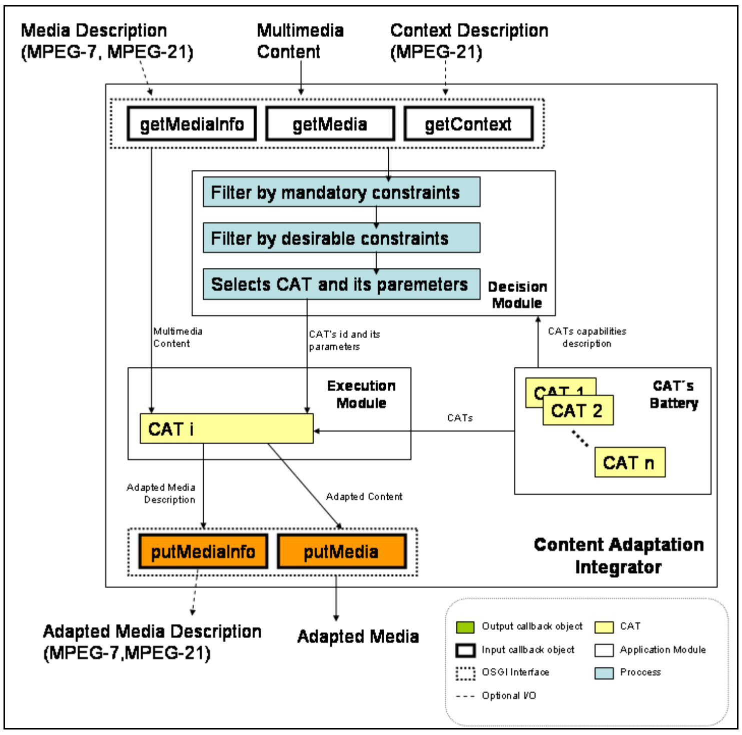

Media Description (MPEG-7, MPEG-21)
Multimedia Content
Context Description (MPEG-21)
getMediaInfo
getMedia
getContext
Filter by mandatory constraints
Filter by desirable constraints
Selects CAT and its paremeters
Decision Module
Multimedia Content
CAT's id and its parameters
CATs capabilities description
Execution Module
CAT i
CATs
CAT 1
CAT 2
CAT n
CAT's Battery
Adapted Media Description
Adapted Content
putMediaInfo
putMedia
Content Adaptation Integrator
Adapted Media Description (MPEG-7,MPEG-21)
Adapted Media
Output callback object
Input callback object
OSGI Interface
Optional I/O
CAT
Application Module
Process

Figure C-1: CAIN Architecture (Image taken from [21])

C.2. Adaptation process

The CATs have to be delivered with a description of their adaptation capabilities, which will be used in the decision module together with the usage preferences, terminal capabilities, network capabilities and content descriptions to select the adequate CAT for the adaptation.

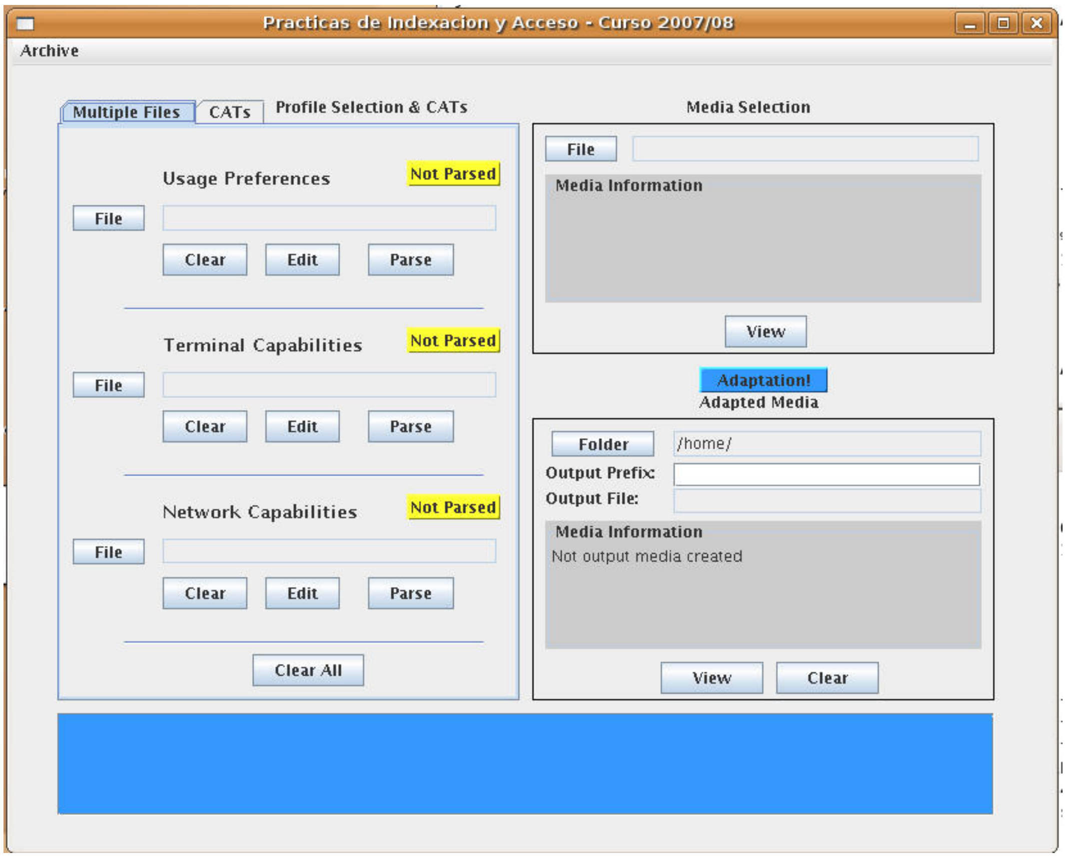
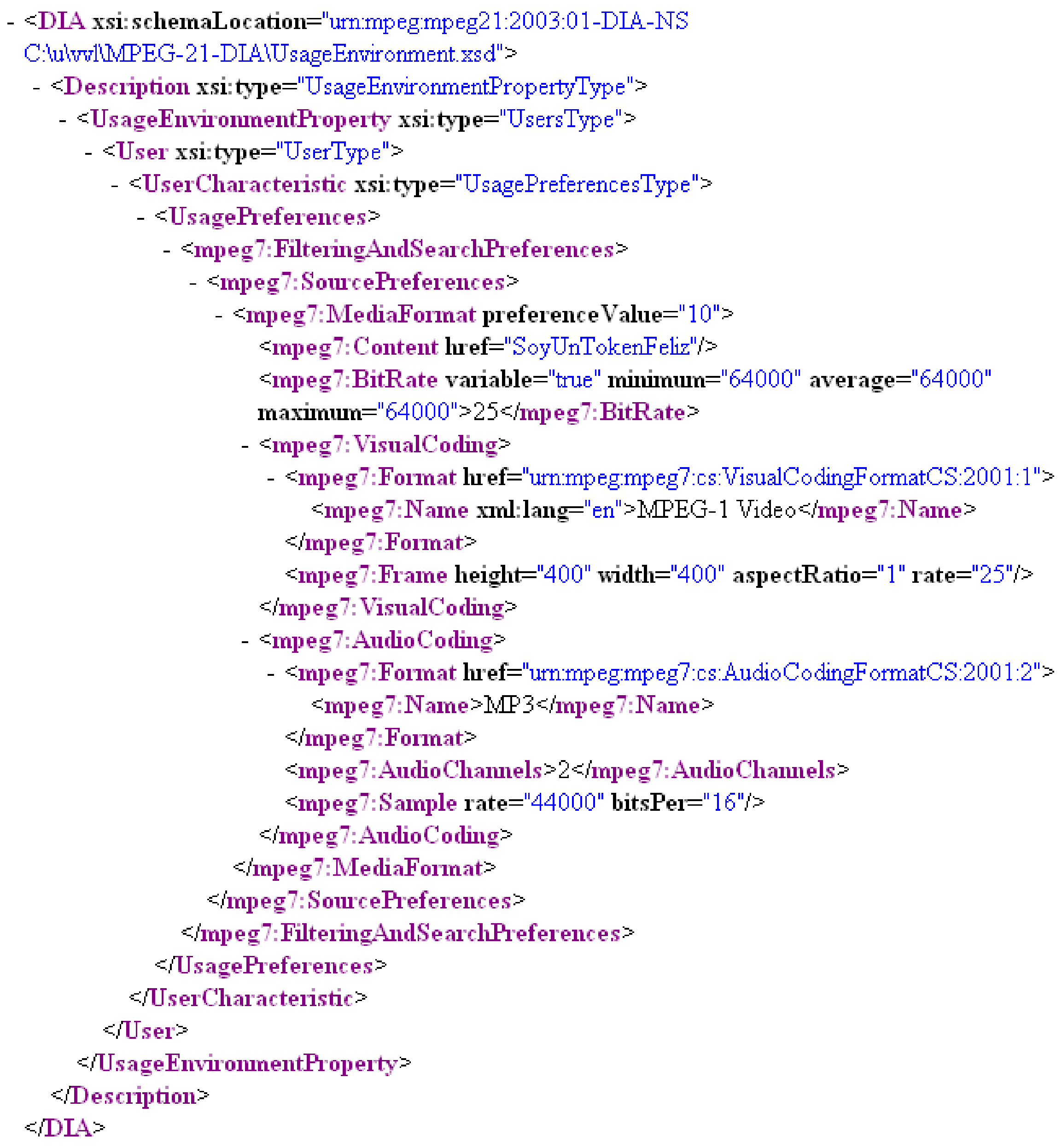


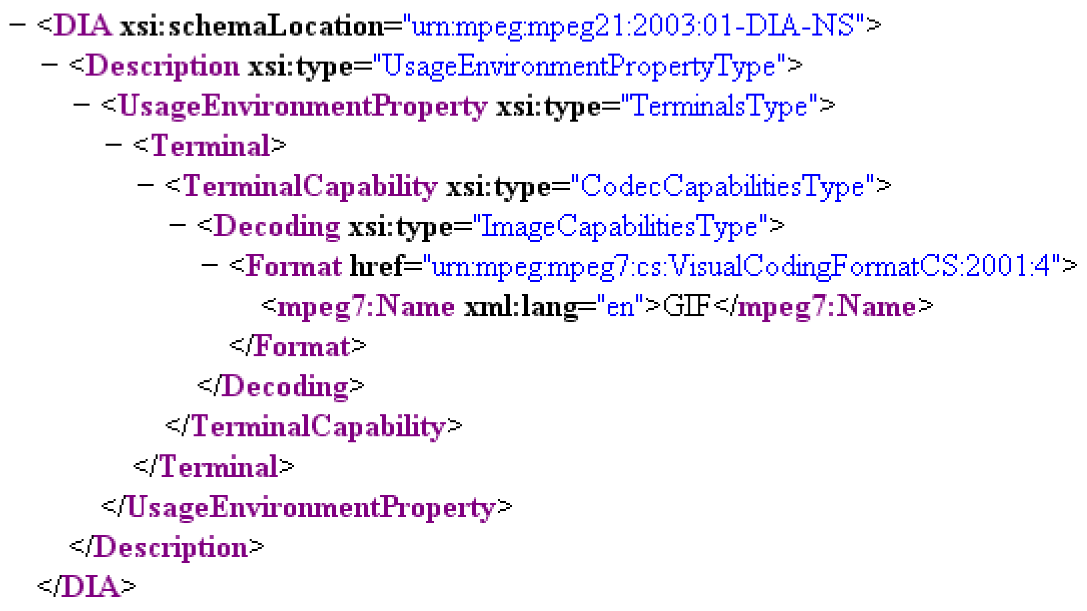
Figure C-2: Appearance of the graphical user interface built internally in the GTI-UAM for demo purposes of the CAIN framework. On the left side of the window the adaptation preference files have to be selected, while on the right side the input file and output filename have to be selected.

The usage preferences, terminal and network capabilities have to be delivered in XML files to allow the work of the decision module. The following are examples of XML files corresponding to the categories enumerated above.



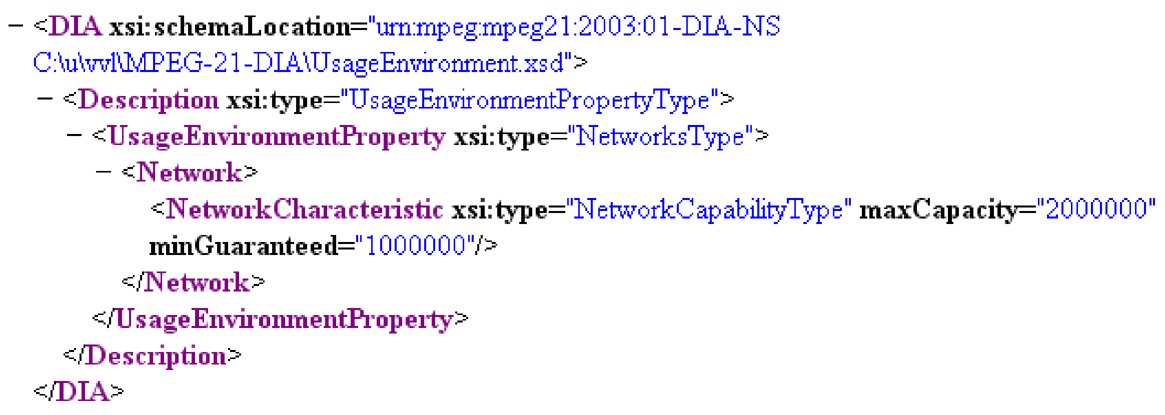
```
- <DIA xsi:schemaLocation="urn:mpeg:mpeg21:2003:01-DIA-NS
  C:\u\wvl\MPEG-21-DIA\UsageEnvironment.xsd">
  - <Description xsi:type="UsageEnvironmentPropertyType">
    - <UsageEnvironmentProperty xsi:type="UsersType">
      - <User xsi:type="UserType">
        - <UserCharacteristic xsi:type="UsagePreferencesType">
          - <UsagePreferences>
            - <mpeg7:FilteringAndSearchPreferences>
              - <mpeg7:SourcePreferences>
                - <mpeg7:MediaFormat preferenceValue="10">
                    <mpeg7:Content href="SoyUnTokenFeliz"/>
                    <mpeg7:BitRate variable="true" minimum="64000" average="64000"
                    maximum="64000">25</mpeg7:BitRate>
                  - <mpeg7:VisualCoding>
                    - <mpeg7:Format href="urn:mpeg:mpeg7:cs:VisualCodingFormatCS:2001:1">
                        <mpeg7:Name xml:lang="en">MPEG-1 Video</mpeg7:Name>
                      </mpeg7:Format>
                      <mpeg7:Frame height="400" width="400" aspectRatio="1" rate="25"/>
                    </mpeg7:VisualCoding>
                  - <mpeg7:AudioCoding>
                    - <mpeg7:Format href="urn:mpeg:mpeg7:cs:AudioCodingFormatCS:2001:2">
                        <mpeg7:Name>MP3</mpeg7:Name>
                      </mpeg7:Format>
                      <mpeg7:AudioChannels>2</mpeg7:AudioChannels>
                      <mpeg7:Sample rate="44000" bitsPer="16"/>
                    </mpeg7:AudioCoding>
                  </mpeg7:MediaFormat>
                </mpeg7:SourcePreferences>
              </mpeg7:FilteringAndSearchPreferences>
            </UsagePreferences>
          </UserCharacteristic>
        </User>
      </UsageEnvironmentProperty>
    </Description>
  </DIA>
```

a. Usage preferences description: The file establishes some of the output preferences, such as the video bitrate, the video resolution and others



```
− <DIA xsi:schemaLocation="urn:mpeg:mpeg21:2003:01-DIA-NS">
  − <Description xsi:type="UsageEnvironmentPropertyType">
    − <UsageEnvironmentProperty xsi:type="TerminalsType">
      − <Terminal>
        − <TerminalCapability xsi:type="CodecCapabilitiesType">
          − <Decoding xsi:type="ImageCapabilitiesType">
            − <Format href="urn:mpeg:mpeg7:cs:VisualCodingFormatCS:2001:4">
                <mpeg7:Name xml:lang="en">GIF</mpeg7:Name>
              </Format>
            </Decoding>
          </TerminalCapability>
        </Terminal>
      </UsageEnvironmentProperty>
    </Description>
  </DIA>
```

b. Terminal capability description: In this example file, the terminal can display GIF files



```
− <DIA xsi:schemaLocation="urn:mpeg:mpeg21:2003:01-DIA-NS
  C:\u\wvl\MPEG-21-DIA\UsageEnvironment.xsd">
  − <Description xsi:type="UsageEnvironmentPropertyType">
    − <UsageEnvironmentProperty xsi:type="NetworksType">
      − <Network>
          <NetworkCharacteristic xsi:type="NetworkCapabilityType" maxCapacity="2000000"
          minGuaranteed="1000000"/>
        </Network>
      </UsageEnvironmentProperty>
    </Description>
  </DIA>
```

c. Network capability description: The description shows a network with a high transfer rate capability.

The decision module selects the best CAT using a constraints satisfaction and optimization algorithm. The constraints are distinguished in two classes: mandatory and desirable.

In the last step, the execution module executes the selected CAT, calling the adaptation method of the chosen CAT.

C.3. CAIN extensibility

CAIN provides a flexible extensibility mechanism in order to integrate new or update existing CATs without having to recode or recompile the core of CAIN. To inform the decision module about the new CAT capabilities, it is required to enclose a file with the CAT's adaptation capabilities.

Besides, all the CATs are forced to implement a common adaptation method that provides a generic interface and performs the adaptations. This method will be called by the execution module and will return a list with the paths and formats of the adapted contents.

More about the integration of a CAT and the particular integration of the Image2VideoCAT into the CAIN architecture can be consulted in chapter 5.2.

D OpenCV

OpenCV – Open Source Computer Vision – is a library of programming functions in C/C++ mainly aimed at real time computer vision. Some example applications of the OpenCV library are Object Identification, Segmentation and Recognition, Face Recognition, Motion Tracking etc.

OpenCV is operative system and hardware independent and is optimized for real time applications. It consists of four principal function libraries: CxCore, CvReference, CvAux and HighGui, which will be detailed in the following points. (The full documentation can be found int the URL http://opencvlibrary.sourceforge.net/)

D.1 CxCore

This library implements the data structures and necessary functions to manage images and associated data, as well as the linear algebra functions:

- **Structures:** These structures go from basic definitions of a point or a rectangle up to an image structure to load its header and the pixel information.

Name	Description
CvPoint, CvPoint2D32f, CvPoint3D32f...	Points in 2D or 3D with coordinates in integer or floating point precision
CvSize, CvSize2D32f	Rectangular dimensions in pixels
CvRect	Rectangular dimensions with offset
CvMat, CvMatND, CvSparseMat	Different multidimensional and/or multichannel matrixes
IplImage	IPL – Intel Image Processing Library – image header. Contains the necessary fields for the image description and a pointer to the image data itself (see chapter 3.3.1 Image structure).

Table 6: Structures implemented in CxCore

- **Dynamic structures:** OpenCV also provides a complete set of data storage structures. Each dynamic structure is delivered with the complete implementation of the insertion, deletion and extraction functions.

Name	Description
CvMemStorage	Dinamically growing memory storage, that expands automatically as needed
CvSeq	Growable sequence of elements
CvSet	Sets/Collection of nodes
CvGraph	Oriented or unoriented weigted graph

Table 7: Dynamic structures implemented in CxCore

For the development of the ROIs2Video application only CvSeq (and indirectly the CvMemStorage) were used.

- **Functions and operations:** The following table contains a short classification of the functions in CxCore.

	Notes	Classification
Operations on arrays	Functions to manipulate the image and matrix data structures	Initialization and accessing elements and sub-arrays
		Copying and filling
		Transforms and permutations
		Arithmetic, Logic and Comparison
		Statistics
		Linear algebra
		Math functions
		Random Number generation
		Discrete transforms
Drawing functions	Funcions to draw on an image, specially used for debugging and marking of ROIs	Lines
		Shapes (Rectangles, circles, ellipses)
		Text
		Point sets and contours
File storage functions	Writing and reading data to/from XML or YAML formatted files…	-
Other miscellaneous functions	-	-

Table 8: Functions and operations in CxCore

D.2 CvReference

For most applications, CvReference is the main library of OpenCV functions. However, for the development of the ROIs2Video tool, only the pattern recognition played a major role. Therefore the pattern recognition in OpenCV, concretely the Viola-Jones face detection method, was described in detail in 2.3.1, while the other function families are only summarized in this table.

	Classification
Image Processing	Gradients, Edges and Corners
	Sampling, Interpolation and Geometrical Transforms
	Morphological Operations
	Filters and Color Conversion
	Pyramids and the Applications
	Connected Components and Contour Retrieval
	Image and Contour Moments
	Special Image Transforms

	Histograms
	Matching
Structural Analysis	Contour Processing
	Computational Geometry
	Planar Subdivisions
Motion Analysis and Object Tracking	Accumulation of Background Statistics
	Motion Templates
	Object Tracking
	Optical Flow
	Estimators
Camera Calibration and 3D Reconstruction	Camera Calibration
	Pose Estimation
	Epipolar Geometry
Pattern recognition	Object detection (See 2.3.1 for more information about the particular case of Face Detection.)

Table 9: Function classification in CvReference

D.3 CvAux

This library contains experimental and obsolete functions:

Operation classification	**Description**
Stereo Correspondence Functions	FindStereoCorrespondence
View Morphing Functions	MakeScanlines
	PreWarpImage
	FindRuns
	DynamicCorrespondMulti
	MakeAlphaScanlines
	MorphEpilinesMulti
	PostWarpImage
	DeleteMoire
3D Tracking Functions	3dTrackerCalibrateCameras
	3dTrackerLocateObjects
Eigen Objects (PCA) Functions	CalcCovarMatrixEx
	CalcEigenObjects
	CalcDecompCoeff
	EigenDecomposite
	EigenProjection
Embedded Hidden Markov Models Functions	HMM
	ImgObsInfo
	Create2DHMM
	Release2DHMM
	CreateObsInfo
	ReleaseObsInfo
	ImgToObs_DCT
	UniformImgSegm

	InitMixSegm
	EstimateHMMStateParams
	EstimateTransProb
	EstimateObsProb
	EViterbi
	MixSegmL2

Table 10: Function classification in CvAux

D.4 HighGUI

HighGUI is a set of functions to design quick and experimental user interfaces. However, the library is not intended for end-user applications, as it only provides simple methods to display images or allow some user interaction.

The HighGUI library also has functions to manage image files, loading them or writing them to disk. The video I/O functions allow the developer to easily use camera input, but does not include exhaustive error handling.

Operation classification	Description
Simple GUI	Functions to open windows that present images and trackbars and functions to listen to mouse or key events.
Loading and saving images	Read and write images in different file formats (BMP, JPEG, PNG, TIFF etc.).
Video I/O functions	Video capturing from a file or a camera
Utility and system functions	

Table 11: Function classification in HighGUI

E Ffmpeg

The Ffmpeg library[10] collection was started by Fabrice Bellard and was named after the MPEG - Moving Pictures Expert Group - video standards group with the prefix *ff* (for *fast forward*). The Ffmpeg software is a command line tool which allows

- to convert digital audio and video between various formats
- to generate videos from an array of image files
- streaming real time video from a TV card

It consists of different components, summarized in the following table:

Library	Description
Libavcodec	Audio/video encoders and decoders. Some of the supported codecs are shown in Table 13
Libavformat	Multiplexers and demultiplexers for audio/video
Libavutils	Auxiliary library
Libpostproc	Video postprocessing routine library
Libswscale	Image scaling routine library

Table 12: Components of Ffmpeg

Multimedia compression formats accepted in Ffmpeg			
Video compression	**ISO/IEC**	**ITU-T**	**Others**
	MPEG-1 MPEG-2 MPEG-4	H.261 H.263 H.264	WMV 7 VC1 RealVideo 1.0 & 2.0
Audio compression	**ISO/IEC**		**Others**
	MPEG-1 Layer III (MP3) MPEG-1 Layer II MPEG-1 Layer I AAC		AC3 ATRAC3 RealAudio WMA
Image compression	**ISO/IEC/ITU-T**		**Others**
	JPEG PNG		GIF TIFF

Table 13: Most important multimedia compression formats accepted in Ffmpeg

[10] http://ffmpeg.mplayerhq.hu/

PRESUPUESTO

1) Ejecución Material

- Compra de ordenador personal (Software incluido)....... .... 2.000 €
- Material de oficina .... 150 €
- Total de ejecución material .... 2.150 €

2) Gastos generales

- 16 % sobre Ejecución Material .... 344 €

3) Beneficio Industrial

- 6 % sobre Ejecución Material .... 129 €

4) Honorarios Proyecto

- 800 horas a 15 € / hora .... 12.000 €

5) Material fungible

- Gastos de impresión .... 60 €
- Encuadernación .... 200 €

6) Subtotal del presupuesto

- Subtotal Presupuesto .... 14.410 €

7) I.V.A. aplicable

- 16% Subtotal Presupuesto .... 2.305,6 €

8) Total presupuesto

- Total Presupuesto .... 16.715,6 €

Madrid, Septiembre de 2007

El Ingeniero Jefe de Proyecto

Fdo.: Fernando Harald Barreiro Megino
Ingeniero Superior de Telecomunicación

PLIEGO DE CONDICIONES

Este documento contiene las condiciones legales que guiarán la realización, en este proyecto, de un "Sistema de Adaptación de Imágenes a Vídeo" para ser visto en pantallas de baja resolución. En lo que sigue, se supondrá que el proyecto ha sido encargado por una empresa cliente a una empresa consultora con la finalidad de realizar dicho sistema. Dicha empresa ha debido desarrollar una línea de investigación con objeto de elaborar el proyecto. Esta línea de investigación, junto con el posterior desarrollo de los programas está amparada por las condiciones particulares del siguiente pliego.

Supuesto que la utilización industrial de los métodos recogidos en el presente proyecto ha sido decidida por parte de la empresa cliente o de otras, la obra a realizar se regulará por las siguientes:

Condiciones generales

1. La modalidad de contratación será el concurso. La adjudicación se hará, por tanto, a la proposición más favorable sin atender exclusivamente al valor económico, dependiendo de las mayores garantías ofrecidas. La empresa que somete el proyecto a concurso se reserva el derecho a declararlo desierto.

2. El montaje y mecanización completa de los equipos que intervengan será realizado totalmente por la empresa licitadora.

3. En la oferta, se hará constar el precio total por el que se compromete a realizar la obra y el tanto por ciento de baja que supone este precio en relación con un importe límite si este se hubiera fijado.

4. La obra se realizará bajo la dirección técnica de un Ingeniero Superior de Telecomunicación, auxiliado por el número de Ingenieros Técnicos y Programadores que se estime preciso para el desarrollo de la misma.

5. Aparte del Ingeniero Director, el contratista tendrá derecho a contratar al resto del personal, pudiendo ceder esta prerrogativa a favor del Ingeniero Director, quien no estará obligado a aceptarla.

6. El contratista tiene derecho a sacar copias a su costa de los planos, pliego de condiciones y presupuestos. El Ingeniero autor del proyecto autorizará con su firma las copias solicitadas por el contratista después de confrontarlas.

7. Se abonará al contratista la obra que realmente ejecute con sujeción al proyecto que sirvió de base para la contratación, a las modificaciones autorizadas por la superioridad o a las órdenes que con arreglo a sus facultades le hayan comunicado por escrito al Ingeniero Director de obras siempre que dicha obra se haya ajustado a los preceptos de los pliegos de condiciones, con arreglo a los cuales, se harán las modificaciones y la valoración de las diversas unidades sin que el importe total pueda exceder de los presupuestos aprobados. Por consiguiente, el número de unidades que se consignan en el proyecto o en el presupuesto, no podrá servirle de fundamento para entablar reclamaciones de ninguna clase, salvo en los casos de rescisión.

8. Tanto en las certificaciones de obras como en la liquidación final, se abonarán los trabajos realizados por el contratista a los precios de ejecución material que figuran en el presupuesto para cada unidad de la obra.

9. Si excepcionalmente se hubiera ejecutado algún trabajo que no se ajustase a las condiciones de la contrata pero que sin embargo es admisible a juicio del Ingeniero Director de obras, se dará conocimiento a la Dirección, proponiendo a la vez la rebaja de precios que el Ingeniero estime justa y si la Dirección resolviera aceptar la obra, quedará el contratista obligado a conformarse con la rebaja acordada.

10. Cuando se juzgue necesario emplear materiales o ejecutar obras que no figuren en el presupuesto de la contrata, se evaluará su importe a los precios asignados a otras obras o materiales análogos si los hubiere y cuando no, se discutirán entre el Ingeniero Director y el contratista, sometiéndolos a la aprobación de la Dirección. Los nuevos precios convenidos por uno u otro procedimiento, se sujetarán siempre al establecido en el punto anterior.

11. Cuando el contratista, con autorización del Ingeniero Director de obras, emplee materiales de calidad más elevada o de mayores dimensiones de lo estipulado en el proyecto, o sustituya una clase de fabricación por otra que tenga asignado mayor precio o ejecute con mayores dimensiones cualquier otra parte de las obras, o en general, introduzca en ellas cualquier modificación que sea beneficiosa a juicio del Ingeniero Director de obras, no tendrá derecho sin embargo, sino a lo que le correspondería si hubiera realizado la obra con estricta sujeción a lo proyectado y contratado.

12. Las cantidades calculadas para obras accesorias, aunque figuren por partida alzada en el presupuesto final (general), no serán abonadas sino a los precios de la contrata, según las condiciones de la misma y los proyectos particulares que para ellas se formen, o en su defecto, por lo que resulte de su medición final.

13. El contratista queda obligado a abonar al Ingeniero autor del proyecto y director de obras así como a los Ingenieros Técnicos, el importe de sus respectivos honorarios facultativos por formación del proyecto, dirección técnica y administración en su caso, con arreglo a las tarifas y honorarios vigentes.

14. Concluida la ejecución de la obra, será reconocida por el Ingeniero Director que a tal efecto designe la empresa.

15. La garantía definitiva será del 4% del presupuesto y la provisional del 2%.

16. La forma de pago será por certificaciones mensuales de la obra ejecutada, de acuerdo con los precios del presupuesto, deducida la baja si la hubiera.

17. La fecha de comienzo de las obras será a partir de los 15 días naturales del replanteo oficial de las mismas y la definitiva, al año de haber ejecutado la provisional, procediéndose si no existe reclamación alguna, a la reclamación de la fianza.

18. Si el contratista al efectuar el replanteo, observase algún error en el proyecto, deberá comunicarlo en el plazo de quince días al Ingeniero Director de obras, pues transcurrido ese plazo será responsable de la exactitud del proyecto.

19. El contratista está obligado a designar una persona responsable que se entenderá con el Ingeniero Director de obras, o con el delegado que éste designe, para todo relacionado con ella. Al ser el Ingeniero Director de obras el que interpreta el proyecto, el contratista deberá consultarle cualquier duda que surja en su realización.

20. Durante la realización de la obra, se girarán visitas de inspección por personal facultativo de la empresa cliente, para hacer las comprobaciones que se crean oportunas. Es

obligación del contratista, la conservación de la obra ya ejecutada hasta la recepción de la misma, por lo que el deterioro parcial o total de ella, aunque sea por agentes atmosféricos u otras causas, deberá ser reparado o reconstruido por su cuenta.

21. El contratista, deberá realizar la obra en el plazo mencionado a partir de la fecha del contrato, incurriendo en multa, por retraso de la ejecución siempre que éste no sea debido a causas de fuerza mayor. A la terminación de la obra, se hará una recepción provisional previo reconocimiento y examen por la dirección técnica, el depositario de efectos, el interventor y el jefe de servicio o un representante, estampando su conformidad el contratista.

22. Hecha la recepción provisional, se certificará al contratista el resto de la obra, reservándose la administración el importe de los gastos de conservación de la misma hasta su recepción definitiva y la fianza durante el tiempo señalado como plazo de garantía. La recepción definitiva se hará en las mismas condiciones que la provisional, extendiéndose el acta correspondiente. El Director Técnico propondrá a la Junta Económica la devolución de la fianza al contratista de acuerdo con las condiciones económicas legales establecidas.

23. Las tarifas para la determinación de honorarios, reguladas por orden de la Presidencia del Gobierno el 19 de Octubre de 1961, se aplicarán sobre el denominado en la actualidad "Presupuesto de Ejecución de Contrata" y anteriormente llamado "Presupuesto de Ejecución Material" que hoy designa otro concepto.

Condiciones particulares

La empresa consultora, que ha desarrollado el presente proyecto, lo entregará a la empresa cliente bajo las condiciones generales ya formuladas, debiendo añadirse las siguientes condiciones particulares:

1. La propiedad intelectual de los procesos descritos y analizados en el presente trabajo, pertenece por entero a la empresa consultora representada por el Ingeniero Director del Proyecto.

2. La empresa consultora se reserva el derecho a la utilización total o parcial de los resultados de la investigación realizada para desarrollar el siguiente proyecto, bien para su publicación o bien para su uso en trabajos o proyectos posteriores, para la misma empresa cliente o para otra.

3. Cualquier tipo de reproducción aparte de las reseñadas en las condiciones generales, bien sea para uso particular de la empresa cliente, o para cualquier otra aplicación, contará con autorización expresa y por escrito del Ingeniero Director del Proyecto, que actuará en representación de la empresa consultora.

4. En la autorización se ha de hacer constar la aplicación a que se destinan sus reproducciones así como su cantidad.

5. En todas las reproducciones se indicará su procedencia, explicitando el nombre del proyecto, nombre del Ingeniero Director y de la empresa consultora.

6. Si el proyecto pasa la etapa de desarrollo, cualquier modificación que se realice sobre él, deberá ser notificada al Ingeniero Director del Proyecto y a criterio de éste, la empresa consultora decidirá aceptar o no la modificación propuesta.

7. Si la modificación se acepta, la empresa consultora se hará responsable al mismo nivel que el proyecto inicial del que resulta el añadirla.

8. Si la modificación no es aceptada, por el contrario, la empresa consultora declinará toda responsabilidad que se derive de la aplicación o influencia de la misma.

9. Si la empresa cliente decide desarrollar industrialmente uno o varios productos en los que resulte parcial o totalmente aplicable el estudio de este proyecto, deberá comunicarlo a la empresa consultora.

10. La empresa consultora no se responsabiliza de los efectos laterales que se puedan producir en el momento en que se utilice la herramienta objeto del presente proyecto para la realización de otras aplicaciones.

11. La empresa consultora tendrá prioridad respecto a otras en la elaboración de los proyectos auxiliares que fuese necesario desarrollar para dicha aplicación industrial, siempre que no haga explícita renuncia a este hecho. En este caso, deberá autorizar expresamente los proyectos presentados por otros.

12. El Ingeniero Director del presente proyecto, será el responsable de la dirección de la aplicación industrial siempre que la empresa consultora lo estime oportuno. En caso contrario, la persona designada deberá contar con la autorización del mismo, quien delegará en él las responsabilidades que ostente.