Chapter 4
Detecting Significant Changes in Image Sequences

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ABSTRACT

In this chapter the authors propose an overview on contemporary artificial intelligence techniques designed for change detection in image and video sequences. A variety of image features have been analyzed for content presentation at a low level. In attempt towards high-level interpretation by a machine, a novel approach to image comparison has been proposed and described in detail. It utilizes techniques of salient point detection, video scene identification, spatial image segmentation, feature extraction and analysis. Metrics implemented for image partition matching enhance performance and quality of the results, which has been proved by several estimations. The review on estimation measures is also given along with references to publicly available test datasets. Conclusion is provided in relation to trends of future development in image and video processing.

INTRODUCTION

Image processing is traditionally related to artificial intelligence issues that try imitating mental activity of visual information perception. Despite of variety of existing methods and content presentation models, the main challenge they face is the gap between information retrieved at a low level and semantic interpretation at a high level required for efficient understanding. In context of bridging the 'semantic gap' paradigm, inspired by tending to richness of human visual perception, image similarity evaluation should be sufficiently well-defined in terms of feature spaces and, at the same time, it should provide enough meaningful information for semantic associations. Low-level features include without limitation color and texture analysis, motion, area and shape analysis. High-level features include but not limited to eigenimages, deformable intensity surfaces, intensity surface curvature histogram. Feature extraction is usually implemented through artificial intelligence methods among which are neural networks, genetic

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algorithms, clustering, statistical analysis, etc. Many of these popular approaches are briefly touched in this chapter.

A set of more complicated questions arises when comparing a bunch of images. These assume not only a single image recognition, but also some comparison procedure that requires differentiation of lighting conditions and camera characteristics with which an image was shot. Image size and resolution also have dramatic impact on the observed changes in image sequences. By an 'image sequence' we mean video frames or any consequentially shot pictures with small time lapse between the shots. (Actually, any video is just a huge number of static images that change each other in dynamics with the speed up to 25-30 times per second.) All the mentioned above is the reason why image and video processing attracts more and more research and development efforts. Still it turns out hard to distinguish objects from a background under noisy conditions, shades and overlapping between them. A short overview on recent achievements in searching for significant content or redundancy elimination (e.g. finding similar content, least common content, best representatives, duplicate removal) is provided.

To overcome the aforementioned problems of overlapping and distinguishing, spatio-temporal segmentation is studied. Spatial image segmentation corresponds to partitioning an image field of view into tessellations of arbitrary or strictly defined shape, regions of interest, or real objects. Particular attention is given to Voronoi diagrams as a geometrical apparatus for image segmentation with further comparison and change detection using specialized metrics. This approach was deeply studied in authors' scientific research while executing governmental and commercial research projects. It turned out to be much more efficient than traditional object-based segmentation and salient point analysis for the purpose of video frame summarization. One of higher order Voronoi diagram properties lies in ability to limit initial number of salient points with simultaneous increase in a number of Voronoi regions. All in all, it is a reasonable compromise between segmentation into real objects and analyzing separate points, being in fact an approximation of segmented regions found by points. Point-based approaches are also examined.

Temporal segmentation is referred to scene boundary detection when speaking about image sequence from video. A brief overview of these techniques is also provided. Changes between video frames emerge quite quickly, and the greatest challenge of real-time qualitative processing still remains. Nearly half a thousand state-of-the-art articles and books were analyzed to make this short review on image processing. By analyzing those cutting-edge approaches and methods, the main common drawbacks were revealed. Conclusions concerning benefits and disadvantages of the examined algorithms and basic tendencies of their development are marked in this chapter.

The main objective of the chapter is to provide a comprehensive overview on the recent trends in image and video processing, and content change detection in particular, provide a complete list of traditional test collections and a review on image processing evaluation techniques. Along with brief observation of legacy image and video processing techniques, the authors' approach to change detection is given in more detail. Numerous schemata, comparative tables, figures and formulas provided in this chapter aid in understanding the given material.

BACKGROUND FEATURE ANALYSIS

Understanding of image content can be presented as an attempt of finding relation between initial images and real-world models. Transition from initial images to models decreases the amount of information contained in an image to a limited sufficient amount of data concerning the object of interest. As a rule,