Signal Processing: *Image Communication* 42 (2016) 59–78

Contents lists available at ScienceDirect

Signal Processing: *Image Communication*

journal homepage: www.elsevier.com/locate/image

HEVC-based 3D holoscopic video coding using self-similarity compensated prediction

Caroline Conti *, Luís Ducla Soares, Paulo Nunes

Instituto Universitário de Lisboa (ISCTE–IUL), Instituto de Telecomunicações, Lisboa Portugal

A R T I C L E I N F O

Article history:
Received 11 August 2015
Received in revised form
12 December 2015
Accepted 18 January 2016
Available online 25 January 2016

Keywords:
3D holoscopic video
Integral imaging
Light field
Plenoptic imaging
3D video coding
HEVC

A B S T R A C T

Holoscopic imaging, also known as integral, light field, and plenoptic imaging, is an appealing technology for glassless 3D video systems, which has recently emerged as a prospective candidate for future image and video applications, such as 3D television. However, to successfully introduce 3D holoscopic video applications into the market, adequate coding tools that can efficiently handle 3D holoscopic video are necessary. In this context, this paper discusses the requirements and challenges for 3D holoscopic video coding, and presents an efficient 3D holoscopic coding scheme based on High Efficiency Video Coding (HEVC). The proposed 3D holoscopic codec makes use of the self-similarity (SS) compensated prediction concept to efficiently explore the inherent correlation of the 3D holoscopic content in Intra- and Inter-coded frames, as well as a novel vector prediction scheme to take advantage of the peculiar characteristics of the SS prediction data. Extensive experiments were conducted, and have shown that the proposed solution is able to outperform HEVC as well as other coding solutions proposed in the literature. Moreover, a consistently better performance is also observed for a set of different quality metrics proposed in the literature for 3D holoscopic content, as well as for the visual quality of views synthesized from decompressed 3D holoscopic content.

1. Introduction

Three dimensional (3D) video technologies are continuously maturing to provide more immersive visual experiences to the end-users. Although the public acceptance of the current 3D stereo technology is far from what the industry expected, the research on alternative 3D acquisition and display systems has been rapidly progressing [1–3].

In this context, holoscopic imaging – also known as integral, light field, and plenoptic imaging – derives from the fundamentals of light field sampling, where not only spatial information about the 3D scene can be captured but also angular, i.e., the “whole observable” (holoscopic) scene. As a result of the used optical system, known as a “fly's eye” microlens array [4] (as shown in Fig. 1), the 3D holoscopic technology allows: (i) capturing a dense number of views with smooth motion parallax in both horizontal and vertical directions [4], (ii) reducing the eye fatigue due to more natural convergence-accommodation cues [5].

Recently, holoscopic imaging has become a promising approach for 3D imaging and sensing, being applied in many different areas of research, such as 3D television [6], image recognition and medical imaging [5]. Moreover, novel initiatives on image and video coding standardization have also considered 3D holoscopic application scenarios, notably: the JPEG working group started recently a new study activity – known as JPEG Pleno [7] – targeting richer image capturing, visualization, and manipulation; the MPEG group started the third phase of Free-viewpoint Television (FTV), in August 2013, targeting

* Corresponding author. Tel.: +351 218418164.
E-mail address: caroline.conti@lx.it.pt (C. Conti).

http://dx.doi.org/10.1016/j.image.2016.01.008
0923-5965/

super multiview, free navigation and full parallax imaging applications [8].

Naturally, the future success of 3D holoscopic video applications in the consumer's market depends on how well various challenges in this type of systems will be overcome. Providing an efficient coding scheme to deal with the large amount of data involved in such systems is a requirement of utmost importance, and will be the main focus of this paper. Although the state-of-the-art HEVC [9] standard is able to fulfill current requirements for high and ultra-high resolution 2D video content, it does not comprise adequate coding tools for the inherent characteristics of 3D holoscopic video content. In fact, in [10], the authors have already presented preliminary results that show that further performance improvements relatively to High Efficiency Video Coding (HEVC) can be reached for 3D holoscopic image coding. This is possible by making use of a self-similarity (SS) compensated prediction.

While addressing the aforementioned challenges, this paper proposes an efficient 3D holoscopic codec for Intra and Inter coding based on HEVC. This solution makes use of the SS compensated prediction to efficiently explore the inherent correlation of the 3D holoscopic content in Intra- and Inter-coded frames. Furthermore, a novel vector prediction scheme is also proposed to take advantage of the distinctive characteristics of the SS prediction data. The proposed prediction scheme is not tuned for any particular optical system since it does not require any explicit knowledge about it (e.g., microlens' size, focal length, and distance of the microlenses to the image sensor).

In addition, relevant 3D holoscopic coding schemes proposed in the literature are reviewed and compared against the proposed solution. To do this, an extensive analysis of the proposed codec for Intra and Inter coding is also provided.

The remainder of this paper is organized as follows. Section 2 reviews the major concepts of holoscopic imaging. Section 3 presents a literature review in terms of 3D holoscopic image and video coding solutions. Section 4 presents the proposed codec architecture for 3D holoscopic video coding based on HEVC, including an efficient SS vector prediction to further improve the proposed coding solution. Section 5 presents test conditions and experimental results; and, finally, Section 6 concludes the paper.

2. Holoscopic imaging technology

In order to better understand the relevant aspects for 3D holoscopic image and video coding, this section overviews the principles behind the holoscopic imaging approach, as well the intrinsic correlations existing in this type of content.

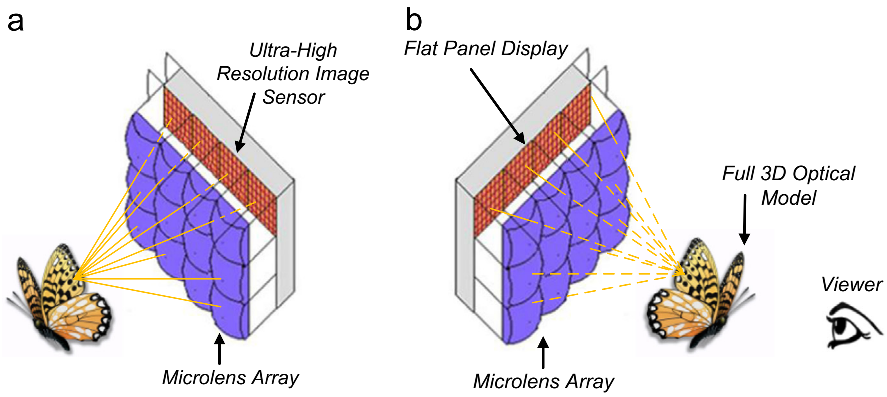

Fig. 1. A holoscopic imaging system: (a) acquisition side; (b) display side.

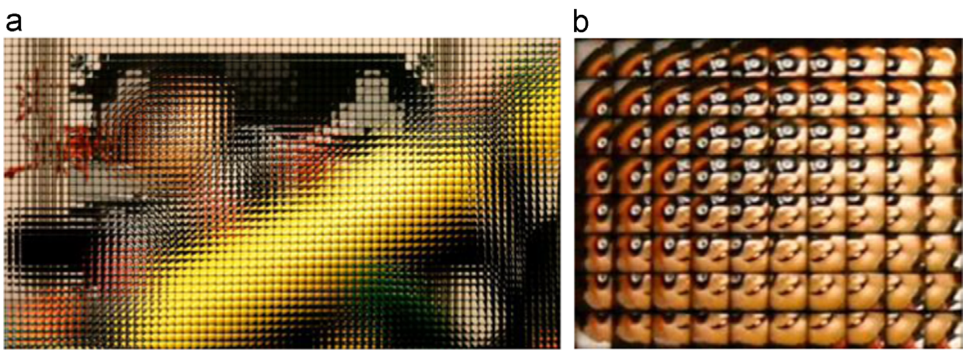

Fig. 2. 3D holoscopic image captured with a 250 μm pitch microlens array: (a) full image with resolution of 1920 × 1088; (b) enlargement of 280 × 224 pixels showing the array of micro-images.