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Depth-image-based rendering for 3DTV service over T-DMB

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ABSTRACT

In this paper, we present a depth-image-based rendering (DIBR) technique for three-dimensional television (3DTV) service over terrestrial-digital multimedia broadcasting (T-DMB). 3DTV service over T-DMB is very attractive because the single user environment of T-DMB is suitable to glassless 3D viewing. However, the bit budget for the transmission of additional data in 3DTV service is very limited in T-DMB. DIBR can resolve this problem because the depth information as the additional data can be compressed effectively. However, DIBR has also some problems such as the backward compatibility with the conventional T-DMB, a large computational cost for rendering virtual images and generation of holes by disocclusion. To solve these problems, we first present the service architecture for DIBR-based 3DTV service over T-DMB, which can maintain the backward compatibility with the conventional T-DMB. Second, we propose a new depth preprocessing method based on adaptive smoothing. In the proposed depth preprocessing method, two adaptive smoothing filters of the discontinuity-preserving smoothing and the gradient direction-based smoothing are sequentially conducted. As a result, both the reduction of bitrates required for the depth transmission and the reduction of the holes can be achieved. Finally, we present look-up table (LUT)-based simultaneous method for generating an auto-stereoscopic image so that problems of the limited memory and the large computational cost can be resolved in T-DMB player. Various experiments show that the proposed DIBR technique can be efficiently employed for 3DTV service over T-DMB.

1. Introduction

Three-dimensional television (3DTV) is regarded as the new broadcasting paradigm that provides a more natural and life-like visual home entertainment experience to a user. The proponents of 3DTV have argued that it will bring the viewer a whole new experience, a fundamental change in the character of the image [17,18]. According to these expectations of 3DTV, many researchers have also paid attention to the development of 3DTV broadcasting technologies. As the result of these efforts, auto-stereoscopic 3D displays based on different perspective views have been developed, and their related services are also introduced successively. Especially, 3DTV service over terrestrial-digital multimedia broadcasting (T-DMB) [20] is one of the promising 3DTV services. T-DMB is one of applications that have emerged from the Eureka-147 DAB system [4]. Particulary, T-DMB focuses on the broadcasting of moving pictures and their reception in harsh conditions, such as in places surrounded by high buildings and on highways where vehicles are moving at a very high speed. Owing to the development of high-quality auto-stereoscopic display devices, which do not require the

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viewer to wear special glasses in order to perceive the depth, 3DTV service over T-DMB has been introduced successfully [2]. 3DTV service over T-DMB has the following advantages. First, it is generally aimed for a single user on the portable player with a small display. Therefore, it is not only easy to implement the glassless 3D viewing but also relatively free from the viewing zone limitation of the auto-stereoscopic display since the user can easily adjust the player for comfortable viewing. Second, visual fatigue for viewing 3D display can be reduced due to a small range of binocular disparity. Third, both the introduction and the commercialization of 3DTV service can be readily facilitated. This is due to the fact that T-DMB has the structural inheritance of the Eureka-147 DAB [4]. Because DAB has commercially been serviced for about a decade in many European countries, it makes sense that new technologies, such as 3DTV service over T-DMB, can be possibly well understood and more accepted to operators in comparison with other mobile multimedia broadcasting systems. Fourth, the mobile market is a large and potentially profitable market in which manufacturers are increasingly looking for new technologies to provide product differentiation [8]. However, there is still room for technical improvement to efficiently implement the advantages of 3DTV service over T-DMB. Currently, 3DTV service over T-DMB is based on an end-to-end stereoscopic video chain [2], in which two separate video streams, one for the left eye and one for the right eye, are captured, transmitted and displayed [17]. In this architecture, however, stereo capturing has to fit to the display geometry and vice versa [6]. Display properties and viewing conditions as well as related human factor aspects have also to be taken into account by the camera man during shooting like Panum's fusional horopter range within which the human visual system is able to merge two separately displayed views into one single stereo percept [13]. Moreover, additional color video stream, which represents the second view in the stereoscopic image, lays a burden of the large transmission overhead on the broadcasting channel with the limited bandwidth. This problem could be more serious in case of mobile broadcasting, such as T-DMB. Although several coding methods, such as the asymmetric coding, have been introduced to solve this problem [7,3], the bit-budget for the transmission of additional video stream is strictly limited in the current state of T-DMB. T-DMB system supports about 2 Mbps of useful data rate in a 1.536 MHz channel. Here, when we consider the bandwidth for conventional video and audio service, additional video stream have to be served in bitrates below about 64 kbps, which are insufficient to compress the additional color video stream efficiently. Recently, the European Information Society Technologies (IST) project 'Advanced Three-Dimensional Television System Technologies' (ATTEST) has proposed depth-image-based rendering (DIBR) technique, in which one or more 'virtual' views of a real-world scene can be generated rapidly at the receiver. DIBR is expected to be the most efficient way to solve above problems of the end-to-end stereoscopic chain as described in detail in [17,6]. Based on this direction of 3DTV service developments, we propose the DIBR technique for 3DTV service over T-DMB. We intend to solve some problems of DIBR, such as depth preprocessing, real-time rendering and backward compatibility with conventional 2D broadcasting in the framework of T-DMB system. The paper is organized as follows. In Section 2, DIBR is reviewed briefly. In Section 3, the service architecture of the proposed methodology is presented. Then, the depth preprocessing method and real-time rendering method are described in Sections 4 and 5, respectively. In Section 6, experimental results are presented. Finally, a conclusion is made in Section 7.

2. Depth-image-based rendering

The recent 3DTV research runs to develop the so-called DIBR techniques [17,6] based on distribution of video-plus-depth data corresponding to only a single, virtual viewing position. DIBR is defined as the process of generating 'virtual' views of a real-world scene from monoscopic color video and associated per-pixel depth information. To maintain the backward compatibility with traditional 2D broadcasting, regular 2D color video in digital TV format is used as it is, and an accompanying depth sequence, which stores depth information of 8-bit gray values with 0 at the furthest place and 255 at the nearest place, is just added with the same spatio-temporal resolution (see Fig. 1). Fig. 2 shows a virtual camera setup for rendering of virtual views. The parameters f and t_c

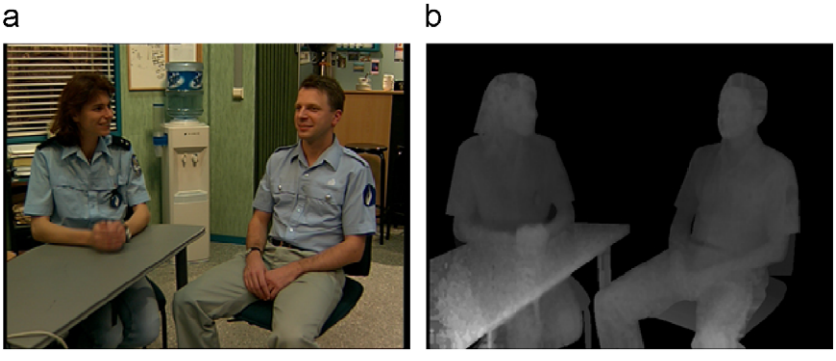

Fig. 1. The example of 3D data representation in DIBR. (a) 'Interview' reference image. (b) Associated depth image.