参考文献

[1] Patrice Rondao Alface, Jean-François Macq, and Nico Verzijp. 2012. Interactive omnidirectional video delivery: A bandwidth-effective approach. *Bell Labs* Technical Journal* 16, 4 (2012), 135–147.

由于很大一部分的带宽被浪费在了传输高质量视频的区域上，而这些区域并没有被显示出来。我们评估了个性化传输的相关性和最优性，其中质量在球形或圆柱形区域中呈结节状，这取决于在实时用户交互过程中它们被查看的可能性。我们基于交互延迟和带宽限制，如何平铺和预测方法可以改进现有的方法。

[2] Trevor Ballard, Carsten Griwodz, Ralf Steinmetz, and Amr Rizk. 2019. RATS:adaptive 360-degree live streaming. In *Proceedings of the 10th ACM Multimedia *Systems Conference*. 308–311.

当只有部分视频（例如当前和预测的视口）以高质量传输而其余的360°视频图块传输时，最新的平铺360°自适应比特率视频流传输方法可节省大量带宽，几乎不会出现停顿的风险质量较低。尽管目前这对于Vod视频方案是可行的，但由于缺乏现有硬件编码器中的切片支持，会产生相当大的开销，因此对于360°实时流提出了一个难题。在本演示中，我们显示实时自适应360流，其中我们利用基于GPU的HEVC编码来实时平铺，编码和缝合不同质量的360°视频。

[3] Yixuan Ban, Lan Xie, Zhimin Xu, Xinggong Zhang, Zongming Guo, and Yue Wang. 2018. Cub360: Exploiting cross-users behaviors for viewport prediction in 360 video adaptive streaming. In *2018 IEEE International Conference on Multimedia and Expo (ICME)*. IEEE, 1–6.

[4] Yanan Bao, Huasen Wu, Tianxiao Zhang, Albara Ah Ramli, and Xin Liu. 2016. Shooting a moving target: Motion-prediction-based transmission for 360-degree videos. In *2016 IEEE International Conference on Big Data (Big Data)*. IEEE, 1161–1170.

[5] Matthias Berning, Takuro Yonezawa, Till Riedel, Jin Nakazawa, Michael Beigl, and Hide Tokuda. 2013. pARnorama: 360 degree interactive video for augmented reality prototyping. In *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*. ACM, 1471–1474.

[6] Jacob Chakareski. 2017. VR/AR immersive communication: Caching, edge computing, and transmission trade-offs. In *Proceedings of the Workshop on Virtual Reality and Augmented Reality Network*. ACM, 36–41.

[7] Gene Cheung, Zhi Liu, Zhiyou Ma, and Jack ZG Tan. 2017. Multi-stream switching for interactive virtual reality video streaming. In *2017 IEEE International Conference on Image Processing (ICIP)*. IEEE, 2179–2183.

[8] Mario Graf, Christian Timmerer, and Christopher Mueller. 2017. Towards Bandwidth Efficient Adaptive Streaming of Omnidirectional Video over HTTP: Design, Implementation, and Evaluation. In *Proceedings of the 8th ACM on Multimedia Systems Conference*. ACM, 261–271.

[9] Xavier Corbillon, Gwendal Simon, Alisa Devlic, and Jacob Chakareski. 2017.Viewport-adaptive navigable 360-degree video delivery. In *2017 IEEE international conference on communications (ICC)*. IEEE, 1–7.

我们调查了各种球面到平面投影和质量安排对显示给用户的视频质量的影响，结果表明，在给定的比特率预算下，立方体贴图布局可提供最佳质量。对用户浏览360度视频的数据集进行的评估表明，分段需要足够短才能启用频繁的视图切换。

[10] Fanyi Duanmu, Zhan Ma, Wei Wang, Meng Xu, and Yao Wang. 2016. A novel screen content fast transcoding framework based on statistical study and machine learning. In *2016 IEEE International Conference on Image Processing (ICIP)*. IEEE,4205–4209.

[11] Ching-Ling Fan, Jean Lee, Wen-Chih Lo, Chun-Ying Huang, Kuan-Ta Chen, and Cheng-Hsin Hsu. 2017. Fixation prediction for 360 video streaming in head mounted virtual reality. In *Proceedings of the 27th Workshop on Network and Operating Systems Support for Digital Audio and Video*. ACM, 67–72.

[12] Vamsidhar Reddy Gaddam, Michael Riegler, Ragnhild Eg, Carsten Griwodz, and Pål Halvorsen. 2016. Tiling in interactive panoramic video: Approaches and evaluation. *IEEE Transactions on Multimedia* 18, 9 (2016), 1819–1831.

[13] Chang Ge, Ning Wang, Severin Skillman, Gerry Foster, and Yue Cao. 2016. QoE driven DASH video caching and adaptation at 5G mobile edge. In *Proceedings of the 3rd ACM Conference on Information-Centric Networking*. ACM, 237–242.

[14] Carsten Griwodz, Mattis Jeppsson, Håvard Espeland, Tomas Kupka, Ragnar Langseth, Andreas Petlund, Peng Qiaoqiao, Chuansong Xue, Konstantin Pogorelov, Micheal Riegler, et al. 2018. Efficient Live and on-Demand Tiled HEVC 360 VR Video Streaming. In *2018 IEEE International Symposium on Multimedia (ISM)*. IEEE, 81–88.https://ieeexplore.ieee.org/document/8603263

随着360°全景视频技术的普及，对于此类视频的高效流式传输方法的需求不断增加。我们超越了现有的按需解决方案，并提出了一种实时流传输系统，该系统在用户视野内的带宽使用和视频质量之间进行了权衡。我们创建了一种将RTP和DASH结合在一起的架构，可将360°VR内容提供给华为机顶盒和三星Galaxy S7。我们的系统多路复用单个HEVC硬件解码器，以提供比传统GOP边界更快的质量切换。我们通过实际实验演示了性能并说明了权衡取舍，在这些实验中，我们可以报告与现有按需方法可比的带宽节省，但是当视野改变时，可以更快地切换质量。

[15] Carsten Griwodz, Frank T Johnsen, Simen Rekkedal, and Pål Halvorsen. 2006. Caching of interactive multiple choice MPEG-4 presentations. In *2006 IEEE International Performance Computing and Communications Conference*. IEEE, 7–pp.

[16] Yu Guan, Chengyuan Zheng, Xinggong Zhang, Zongming Guo, and Junchen Jiang. 2019. Pano: Optimizing 360 video streaming with a better understanding of quality perception. In *Proceedings of the ACM Special Interest Group on Data Communication*. 394–407.

[17] Mohammad Hosseini and Viswanathan Swaminathan. 2016. Adaptive 360 VR video streaming: Divide and conquer. In *2016 IEEE International Symposium on Multimedia (ISM)*. IEEE, 107–110.

我们提出了一种采用分而治之的自适应带宽高效的360 VR视频流系统。我们提出了一种动态的视图感知自适应技术，以解决360 VR视频流的巨大带宽需求。

[18]Afshin Taghavi Nasrabadi, Anahita Mahzari, Joseph D. Beshay, and Ravi Prakash.Adaptive 360-Degree Video Streaming Using Scalable Video Coding. In *Proceedings of the 2017 ACM on Multimedia Conference (MM ’17)*. ACM, 1689–1697.https://doi.org/10.1145/3123266.3123414

[19] Chenge Li, Weixi Zhang, Yong Liu, and Yao Wang. 2019. Very Long Term Field of View Prediction for 360-degree Video Streaming. In *2019 IEEE Conference on Multimedia Information Processing and Retrieval (MIPR)*. IEEE, 297–302.

[20] Xing Liu, Bo Han, Feng Qian, and Matteo Varvello. 2019. LIME: understanding commercial 360° live video streaming services. In *Proceedings of the 10th ACM Multimedia Systems Conference*. ACM, 154–164.

研究人员对投影/编码方法[6,10,25,31,52]、能量消耗[23]、视口自适应流媒体[12,13,15,16,20,32,35,36,45-471、跨层交互[41,48]、用户体验[14]等方面进行了研究。上述研究大多集中在非直播的360视频上，没有一个像我们使用众包（crowd-sourcing.）那样调查商业360视频流平台。（QoE指标包括视频比特率，持续时间和视频冻结的数量，以及用户实时延迟收集了来自不同国家的大量观众。）

[21] Feng Qian, Lusheng Ji, Bo Han, and Vijay Gopalakrishnan. 2016. Optimizing 360 video delivery over cellular networks. In *Proceedings of the 5th Workshop on All Things Cellular: Operations, Applications and Challenges*. ACM, 1–6.

[22] Anahita Mahzari, Afshin Taghavi Nasrabadi, Aliehsan Samiei, and Ravi Prakash.2018. Fov-aware edge caching for adaptive 360 video streaming. In *2018 ACM Multimedia Conference on Multimedia Conference*. ACM, 173–181.

05Fov缓存策略

[23]Stefano Petrangeli, Viswanathan Swaminathan, Mohammad Hosseini, and Filip De Turck. 2017. An HTTP/2-based adaptive streaming framework for 360Âřvirtual reality videos. In *2017 ACM Multimedia (MM) Conference*. 1–9.

[24] Alireza Zare, Alireza Aminlou, Miska M Hannuksela, and Moncef Gabbouj. 2016.HEVC-compliant tile-based streaming of panoramic video for virtual reality applications. In *Proceedings of the 2016 ACM on Multimedia Conference*. ACM,601–605

[25] Cise Midoglu, Özgü Alay, and Carsten Griwodz. 2019. Evaluation Framework for Real-Time Adaptive 360-Degree Video Streaming over 5G Networks. In *Proceed*ings of the 2019 on Wireless of the Students, by the Students, and for the Students*Workshop*. 6–8.

评估real-time 360度视频的端到端分发，并考虑从视频捕获到编码，交付和回放的所有方面，以及及时和适当的分析，重点是最终用户的**体验质量（QoE）**。这需要一个**度量框架**，该框架允许同时从多个维度收集度量。在这项工作中，我们提出了这样一种框架，用于评估实验性的第五代（5G）网络上的实时自适应360度视频流，该框架可用于研究端到端视频交付链的不同方面。

[26] Simone Mangiante, Guenter Klas, Amit Navon, Zhuang GuanHua, Ju Ran, and Marco Dias Silva. 2017. VR is on the Edge: How to Deliver 360-degree Videos in Mobile Networks. In *Proceedings of the Workshop on Virtual Reality and Augmented Reality Network*. ACM, 30–35.

[27] Afshin Taghavi Nasrabadi, Anahita Mahzari, Joseph D Beshay, and Ravi Prakash.2017. Adaptive 360-degree video streaming using scalable video coding. InProceedings of the 25th ACM international conference on Multimedia*. ACM, 1689–1697.

虚拟现实和360度视频流正在快速增长，然而，由于对带宽的高要求，流式传输高质量360度视频仍然面临挑战。现有的解决方案通过仅为用户的视口流传输高质量视频来减少带宽消耗。但是，将空间域（视口）添加到视频适应空间会阻止现有解决方案将未来的视频块缓冲的时间长于用户视口可预测的间隔。由于重新缓冲，这使得回放更容易出现视频死机，这严重降低了用户的体验质量，尤其是在充满挑战的网络条件下。我们提出了一种新方法，该方法通过利用可伸缩视频编码来减轻对缓冲区持续时间的限制。与现有解决方案相比，我们的方法可显着**减少带宽变化的链路上重新缓冲的发生**，而不会影响回放质量或带宽效率。我们利用真实蜂窝网络带宽跟踪的实验结果证明了我们提出的方法的效率。

[28] Urs Niesen and Mohammad Ali Maddah-Ali. 2015. Coded caching for delay sensitive content. In *2015 IEEE International Conference on Communications (ICC)*.IEEE, 5559–5564.

[29] Feng Qian, Lusheng Ji, Bo Han, and Vijay Gopalakrishnan. 2016. Optimizing 360 video delivery over cellular networks. In *Proceedings of the 5th Workshop on All Things Cellular: Operations, Applications and Challenges*. ACM, 1–6.

我们提出了一种基于头部运动预测的手机友好流媒体方案，仅提供360个视频的可视部分。下载子区域，

[30] Rodrigo Silva, Bruno Feijó, Pablo B Gomes, Thiago Frensh, and Daniel Monteiro.2016. Real time 360 video stitching and streaming. In *ACM SIGGRAPH 2016 Posters*. ACM, 70.

在本文中，我们提出了一种针对GPU的实时360°视频拼接和流处理方法。该解决方案为高分辨率创建了可扩展的解决方案，例如每台摄像机4K和8K，并支持具有云体系结构的广播解决方案。该方法使用一组使用OpenGL（GLSL）处理的可变形网格，最终图像使用健壮的像素着色器组合输入。此外，可以使用带有nVEnc GPU编码的h.264编码将结果流式传输到云服务。最后，我们提出一些结果。

[31] Robert Skupin, Yago Sanchez, Cornelius Hellge, and Thomas Schierl. 2016. Tile-based HEVC video for head mounted displays. In *2016 IEEE International Sympol *sium on Multimedia (ISM)*. IEEE, 399–400.

实现视口自适应流的一种更有效的方法是促进运动受限的HEVC切片。保留用户视口中的原始内容分辨率，而当前未呈现给用户的内容以较低的分辨率传递。可以即时进行将不同分辨率的切片轻量级聚合到单个HEVC比特流中，并允许在**终端设备上使用单个解码器**实例。

[32] Jacob Chakareski. 2017. VR/AR Immersive Communication: Caching, Edge Computing, and Transmission Trade-Offs. In *Proceedings of the Workshop on Virtual Reality and Augmented Reality Network*. ACM, 36–41.

[33] Liyang Sun, Fanyi Duanmu, Yong Liu, Yao Wang, Yinghua Ye, Hang Shi, and David Dai. 2019. A two-tier system for on-demand streaming of 360 degree video over dynamic networks. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems* 9, 1 (2019), 43–57.

[34] Yaping Sun, Zhiyong Chen, Meixia Tao, and Hui Liu. 2018. Communication, computing and caching for mobile VR delivery: Modeling and trade-off. In *2018 IEEE International Conference on Communications (ICC)*. IEEE, 1–6.

[35] Afshin TaghaviNasrabadi, Anahita Mahzari, Joseph D Beshay, and Ravi Prakash.2017. Adaptive 360-degree video streaming using layered video coding. In *2017 IEEE Virtual Reality (VR)*. IEEE, 347–348.

映射：现有的视频编码器无法直接对球形视频进行编码。在这方面，视频应在编码之前映射到2D平面。有多种地图投影方法，例如等角，金字塔和立方体投影。|| 编码：自适应360度视频流解决方案将**视频分成几秒**的持续时间，并将每个片段在空间域中切成**切片**。每个图块均以几种质量级别编码。然后，客户端根据视口预测和网络条件请求分段。

[36] Lee, J., Kim, B., Kim, K., Kim, Y., and Noh, J. Rich360: optimized spherical representation from structured panoramic camera arrays. *ACM Transactions on Graphics (TOG) 35*, 4 (2016), 63.

首先，利用可变形的球形投影表面来最小化来自多个摄像机的视差。根据从重叠视频区域估计的深度约束，表面会在时间上发生时空变形。这样就可以独立于视图数量实现快速，高效的无视差拼接。接下来，执行非均匀球形射线采样。采样的密度根据图像区域的重要性而变化。最后，对于交互式查看，然后使用UV贴图将非均匀采样的视频映射到均匀的观察球上。当最终的360°全景视频的分辨率小于输入视频的整体分辨率时，这种方法可以保留输入视频的丰富度，大多数360°全景视频就是这种情况。我们展示了Rich360的各种结果，以证明输出视频的丰富性和拼接结果的先进性。

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[39]

[40] Xiufeng Xie and Xinyu Zhang. 2017. Poi360: Panoramic mobile video telephony over lte cellular networks. In *Proceedings of the 13th International Conference on emerging Networking EXperiments and Technologies*. ACM, 336–349.

互动类视频电话系统

[41]

[42] Alireza Zare, Alireza Aminlou, Miska M Hannuksela, and Moncef Gabbouj. 2016.HEVC-compliant tile-based streaming of panoramic video for virtual reality applications. In *Proceedings of the 24th ACM international conference on Multimedia*.ACM, 601–605

交付广角和高分辨率的球形全景视频内容需要很高的流比特率。原因是HMD（头显）通常需要高的空间和时间保真度内容以及严格的低延迟才能保证用户在使用它们时的临场感。这篇论文**以不同的分辨率存储同一视频内容的两个版本**，每个版本都使用高效视频编码（HEVC）标准划分为多个图块。根据用户当前的视角，将以捕获的最高分辨率传输一组图块，而其余部分则从相同内容的低分辨率版本传输。为了能够随机选择不同的组合，将图块集编码为可独立解码。我们进一步研究了切片方案选择的权衡及其对压缩和流式比特率性能的影响。结果表明，与流式传输整个视频内容相比，根据所选的切片方案，流式传输的比特率节省了30％至40％。

--End--