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MMTC Communications – Review

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Message from the Review Board Directors

Welcome to the August 2018 issue of the IEEE ComSoc MMTC Communications – Review.

This issue comprises four reviews that cover multiple facets of multimedia communication research including spherical superpixel segmentation, audio-visual person identification, D2D communication, and mobile edge collaboration for video distribution. These reviews are briefly introduced below.

The first paper, published in IEEE Transactions on Mutimedia and edited by Dr. Carl James Debono, designed an algorithm to create superpixels, assuming planar images that are not ideal for modern panoramic and 360-degree images.

The second paper is published in IEEE Transactions on Human-Machine Systems and edited by Dr. Mukesh Saini. It proposes a novel method to adapt target models using information from multiple modalities to achieve automatic person identification.

The third paper, published in IEEE Transactions on Communications and edited by Dr. Cong Shen, investigates how to enhance the coverage and spectral efficiency in millimeter-wave cellular network using device-to-device communications.

The fourth paper, published in IEEE Transactions on Multimedia and edited by Dr. Jinbo Xiong studies the approach to video distribution within mobile edge systems, leveraging the social relations among mobile devices/users.

All the authors, nominators, reviewers, editors, and others who contribute to the release of this issue deserve appreciation with thanks.

IEEE ComSoc MMTC Communications – Review Directors

Qing Yang
University of North Texas, USA
Email: qing.yang@unt.edu

Roger Zimmermann
National University of Singapore, Singapore
Email: rogerz@comp.nus.edu.sg

Wei Wang
San Diego State University, USA
Email: wwang@mail.sdsu.edu

Zhou Su
Shanghai University, China
Email: zhousu@ieee.org

Superpixel Segmentation for Spherical Images

A short review for "Spherical Superpixel Segmentation"
Edited by Carl James Debono

Q. Zhao, F. Dai, Y. Ma, L. Wan, J. Zhang, and Y. Zhang, "Spherical Superpixel Segmentation," IEEE Transactions on Multimedia, vol. 20, no. 6, pp. 1406-1417, June 2018.

Superpixel algorithms find widespread use in computer vision and multimedia systems. The generation of superpixels is done by grouping similar pixels together that have a high probability of being part of the same object. In doing so, better spatial contrast is achieved leading to improved feature extraction. Moreover, this grouping means that subsequent computations are reduced yielding faster results. The algorithms developed to create superpixels assume planar images and are not ideal for modern panoramic and 360 degree images.

The image sphere needs to be mapped onto a plane to apply these algorithms. This mapping introduces some distortions impacting the result of the superpixel algorithms [1]. Furthermore, the spherical images need to form a closed surface but this cannot be guaranteed when applying planar solutions. Moreover, regularity in shape and size are preferred in spherical superpixel segmentation. While some planar solutions can generate compact and regular superpixels, such as [2], this uniformity is lost if they are applied to spherical images. These issues arise due to the lack of consideration of the geometry arising from the spherical data.

The authors tackle these issues and come up with a spherical superpixel generation algorithm. The solution resembles the concept of [2] and applies a clustering solution to generate superpixels that exploit the geometry of spherical images. The centers of the superpixels are initialized by using Hammersley points [3] sampled on a sphere. Cosine dissimilarity and spherical distance are then applied to obtain a spatial distance metric that is used to assign pixels and improving the location of the superpixel centers.

The cluster centers, which are the centers of the superpixels, are initialized by sampling the unit sphere. The sampling is done in the LAB color space due to its perceptual uniform property [4]. Each pixel is then assigned to the nearest cluster and the centers are adjusted as the clusters grow. This process is iterative and done in the spherical domain to adhere to the geometry of the images.

The algorithm proposed by the authors avoids placing superpixels on an edge. This is done by moving such initial centers to positions with lowest gradient in a 3×3 neighborhood using the spherical coordinate system. To obtain uniform sampling, Hammersley sampling [5] is adopted. This first generates Hammersley points in 2D unit square which are then mapped to the unit sphere by applying linear scaling and z-preserving radial projection. The Hammersley sampling is used by the authors as it allows more flexibility in generating the required sampling points.

Once the cluster centers are initialized, each pixel is associated to the nearest center. This assignment only considers the neighborhood of the pixel being considered. The search is limited to a neighborhood of size $2S \times 2S$, with S being the size of a superpixel. When all the pixels are associated to a cluster, the cluster centers are updated such that each center would represent the point that minimizes the sum of distances between the point itself and the pixels that are members of that cluster. The assignment and update processes are iterated until convergence or until a defined number of epochs is exceeded. The distance measure used in the cluster center update step calculates the distance between the center of the cluster and the pixel under consideration. This is a function of the color distance as defined in [2] and the spatial distance. The spatial distance is found using cosine dissimilarity to cater for the spherical system. Another solution using the great circle distance is also implemented for comparison.

The authors evaluate the solution with simple linear iterative clustering (SLIC) [2], efficient graph-based segmentation [6] and a panorama version of efficient graph-based segmentation [7]. The comparison is done both quantitatively and qualitatively. The quantitative evaluation is done using boundary recall, under segmentation error, achievable segmentation accuracy, compactness and size variance. The evaluation is done on a modified version of the Berkley Segmentation dataset [8] where the images of the original dataset were rendered on a sphere and flattened to spherical images using equirectangular projection. A small dataset of 12 annotated panoramas is also used for evaluation. Results presented by the authors show good performance of the proposed solutions. Some visual results and the timing performance are presented in the original paper.

Segmentation is clearly an important component in image processing and computer vision and correct superpixel segmentation is essential with current high-resolution content. As more virtual and augmented reality applications enter the market, more algorithms suited for spherical images will be needed. The algorithms will also need lower time complexities for real-time solutions and as image resolutions increase.

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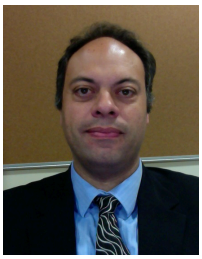
Carl James Debono (S'97, M'01, SM'07) received his B.Eng. (Hons.) degree in Electrical Engineering from the University of Malta, Malta, in 1997 and the Ph.D. degree in Electronics and Computer Engineering from the University of Pavia, Italy, in 2000.



Between 1997 and 2001 he was employed as a Research Engineer in the area of Integrated Circuit Design with the Department of Microelectronics at the University of Malta. In 2000 he was also engaged as a Research Associate with Texas A&M University, Texas, USA. In 2001 he was appointed Lecturer with the Department of Communications and Computer Engineering at the University of Malta and is now an Associate Professor. He is currently the Head of the Department of Communications and Computer Engineering at the University of Malta.

Prof. Debono is a senior member of the IEEE and served as chair of the IEEE Malta Section between 2007 and 2010. He was the IEEE Region 8 Vice-Chair of Technical Activities between 2013 and 2014. He has served on various technical program committees of international conferences and as a reviewer in journals and conferences. His research interests are in multi-view video coding, resilient multimedia transmission, computer vision, and modeling of communication systems.

A Novel Approach for Exploiting Multimodal Information for Person Identification

A short review for "On-line cross-modal adaptation for audio-visual person identification with wearable cameras"

Edited by Mukesh Saini

A. Brutti and A. Cavallaro, " Online Cross-Modal Adaptation for Audio--Visual Person Identification With Wearable Cameras," IEEE Transactions on Human-Machine Systems, vol. 47, no. 1, Feb. 2017.

Automatic person identification involves capturing sensor data, building target model, and using that model to identify the person given a new sensor data samples. In most application scenarios, the environmental conditions as well as target appearance changes rapidly over time. Therefore, it is important to adapt the model parameters with time. There has been works on adapting target model parameters for single modalities individually, such as audio [1] and video [2]. This paper presents a novel way to adapt the target model using information from multiple modalities providing complementary information about the target. The application scenario considered is person re-identification using wearable devices. The complimentary modalities considered are audio and video recorded using wearable sensors. When a video is recorded using a body-worn camera, there are additional challenges in the appearance of a person; the face may not be visible at all times and the camera may capture just a partial view of the body. The authors are using information from audio to make the person identification more robust in this scenario.

One way to combine audio and visual information for person identification is early fusion through feature concatenation. More frequently, independent audio and visual systems are merged at the end, in a late fusion strategy, by combining classification scores. The latter approach is more popular because it is modular and each mono-modal system is designed individually, addressing the peculiarities of the signal under analysis. Hence, there is a separate target model for each modality. The parameters of each mono-modal model are adapted by using the information coming from the other modality. Let us consider a scenario where a light condition change occurs, modifying the appearance model of the targets. A good late fusion approach would discard the visual information, relying on audio only to recognize the person identity. This, however, does not solve the mismatch problem and it is not useful if, in the future, the target is silent. The authors of this paper propose to use the audio information to adapt the visual model to the new light conditions, reducing the amount of mismatch and allowing the visual modality to contribute in recognizing the target identity in the new operational conditions.

The model parameters are adapted with each new observation of the target. Whenever a new observation of a target is made, the feature vector corresponding to that observation is used to adapt the model parameters using a Kalman filter equation. The authors recommend conservative approach in choosing right observation for model adaption. Only those observations should be chosen which provide high posterior probability, e.g., observations with high classification score. The Kalman filter is obtained using an online EM algorithm that maximizes the posterior probability for the given observation, which is also traditionally known as MAP adaption problem [3]. The gain of Kalman filter is calculated using the posterior probability of the complementary modality. For audio and video modalities under consideration, the posterior probability is directly calculated from the classification scores.

Each segment is processed to obtain one feature vector for each modality. MFCC based feature vector is derived from the audio segment. The audio target model is acquired by averaging the feature vector in the initial enrolment stage over a number of segments. One benefit of this approach is that no prior training data is required. To classify a given segment, cosine similarity is measured between the model feature vector and the feature vector obtained from the segment. Video segment is represented using a color histogram, which is similarly averaged over a number of segments in the beginning to acquire initial target model. Classification score is calculated using Bhattacharya distance between model and segment feature vector. Finally,

weighted sum of the scores is calculated to label current segment.

Experiments are conducted on two datasets. First dataset consists of 16 participants giving the same 1-minute talk three times. A camcorder and a lapel microphone record the talks. The second dataset consists of 13 participants interacting for 1 minute with a person wearing chest-mounted camera. The video clips are divided into 5s segments. Each video segment also has corresponding audio segment. The experiments show the benefits and limitations of the proposed approach, with and without late fusion of the classification scores. It is found that without adaptation, audio performs better than video. This is because a person's voice has much less variations than visual appearance. Also, the illumination change does not affect audio. On the other hand, video performs better in noisy environments. Nevertheless, if the illumination is varying too rapidly (which was simulated in a few videos of the dataset), video also performs poorly in the absence of adaption. With model adaptations, both audio and video models perform better in most cases. However, in low SNR conditions, the adaptation may affect the model adversely. Another important limitation of the work is the need to control a parameter that limits, or skips, adaptation of one modality when the other one is highly mismatched.

Acknowledgement:

The R-Letter Editorial Board thanks xxxx for nominating this work.

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Mukesh Saini is an Assistant Professor at IIT Ropar. His research area is multimedia systems, with specialization in surveillance, automatic movie making, and smart classrooms. Mukesh Saini obtained his Master of Technology (M. Tech) in Electronics Design and Technology from Indian Institute of Science (IISc), Bangalore, in 2006 and PhD in Computer Science from School of Computing, National University of Singapore, Singapore in 2012 respectively. Mukesh has been actively serving as Reviewer, TPC member, Tutorial organizer, and Panelist for various reputed conferences and journals.

Enhancing Coverage and Spectral Efficiency using D2D Relays

A short review for "Improving the Coverage and Spectral Efficiency of Millimeter-Wave Cellular Networks using Device-to-Device Relays"

Edited by Cong Shen

S. Wu, R. Atat, N. Mastronarde and L. Liu, "Improving the Coverage and Spectral Efficiency of Millimeter-Wave Cellular Networks using Device-to-Device Relays," IEEE Transactions on Communications, vol. 66, no. 5, May 2018, pp. 2251– 2265.

Millimeter-wave (mmWave) communication is attracting considerable attention from the scientific community and regulators for its potential to fulfill the ever increasing demand for mobile broadband access and high-quality, bandwidth-intense, delay-sensitive multimedia applications [1]. However, due to its weak diffraction ability and severe penetration loss, mmWave communication is highly susceptible to blockages. Consequently, mmWave links require line-of-sight (LOS) paths, causing pronounced coverage holes due to environmental obstacles (buildings, human bodies [2], etc.).

A promising approach to extend coverage in mmWave cellular networks is to allow an intermediate relay node to forward traffic from a BS (base station) to a destination UE (user equipment), which has poor links to nearby BSs. Due to their potential to route around blockages, two-hop relay transmissions can improve mmWave coverage. In general, the relay transmission could be completed in the mmWave or microwave spectrum, and a relay node can either be deployed by an operator (e.g., a so-called *infrastructure relay* in long term evolution (LTE) [3]) or can be an idle UE that is used opportunistically. This latter case is attractive because it does not drastically change the network topology or infrastructure requirements. Since a UE serving as a relay connects to a destination UE via a device-to-device (D2D) link, it is often referred to as a *D2D relay*.

In this paper, the authors analyze the downlink coverage probability and spectral efficiency of a two-hop relay-assisted mmWave cellular network using stochastic geometry [4]. In the considered network, a downlink transmission is switched from direct cellular mode to D2D relay mode if there is an outage of the cellular link, but a relay UE is available that can help complete the transmission from the BS to the destination UE. For D2D transmissions (from relay UEs to destination UEs), both mmWave and microwave (sub 6-GHz) D2D links are possible. The authors investigate both of these options.

The authors begin by deriving the LOS probability between any two network nodes. This analysis assumes cylindrical obstacles distributed according to a 2D homogeneous Poisson point process (PPP). They validate the accuracy of their LOS probability model against the statistical LOS probability obtained using real building data for the ultra-dense Chicago area [5].

They then show that the downlink coverage probability of a relay-assisted mmWave cellular network depends on the coverage of the cellular and D2D links, which are independent when D2D is deployed in the uplink spectrum. Given this coverage model, the problem of deriving the downlink coverage probability reduces to separately deriving the cellular downlink and D2D coverage probabilities. The authors derive the coverage probabilities of mmWave cellular and mmWave D2D links using dominant interferer analysis considering both blockages (based on the derived LOS probability model) and beamforming gains (obtained using an $N \times N$ uniform planar square antenna array [6]). Moreover, they derive the coverage probability for microwave D2D links considering different path loss models for LOS and non-LOS (NLOS) links. They then derive the overall microwave D2D coverage probability using the law of total probability.

Recent research suggests that mmWave networks are likely to be noise-limited rather than interference-limited due to the blockage effect [7], [8]. With the noise-limited assumption, a mmWave link experiences an outage if the SNR (signal-to-noise ratio) at the receiver is below a given SNR outage threshold τ. The authors show that the noise-limited assumption significantly simplifies the coverage probability model and, according to their numerical results, is accurate for lower BS densities and for higher

obstacle densities owing to the lower interference experienced in these scenarios.

In addition to the coverage probabilities, the authors derive the spectral efficiency (SE) of the relay-assisted mmWave cellular downlink. Unlike the downlink SE of a cellular network [9], the downlink SE of a relay-assisted network depends on the *mode selection strategy*, which determines whether a UE is served in direct or relay mode. In this paper, the authors consider a mode selection strategy in which the downlink transmission is switched from direct cellular to D2D relay mode if the cellular link's SINR is below a threshold τ, but a candidate relay UE is available that has SINRs above τ on both the BS-to-relay and relay-to-UE links. In this case, they show that the SE depends on the threshold τ, which they call the *relaying SINR threshold*.

The authors validate their analytical results against simulations based on 3GPP network evaluation scenarios and channel models and explore the effect of different parameters on the performance of relay-assisted mmWave cellular networks. Their results demonstrate that two-hop D2D relays can improve coverage and SE across a variety of network configurations and that microwave D2D relays achieve higher coverage probabilities than mmWave D2D relays, except under extremely dense BS deployments, i.e., dense interferers.

In summary, the authors demonstrate that D2D relays have the potential to route around blockages in mmWave cellular networks, thereby improving not only their coverage, but also their SE. Long-term, such technology is poised to enable breakthroughs in ultra high-definition video streaming and virtual/augmented reality applications deployed over mmWave networks.

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Cong Shen received his B.S. and M.S. degrees, in 2002 and 2004 respectively, from the Department of Electronic Engineering, Tsinghua University, China. He obtained the Ph.D. degree from the Electrical Engineering Department, UCLA, in 2009. From 2009 to 2014, He worked for Qualcomm Research in San Diego, CA. In 2015, he returned to academia and joined University of Science and Technology of China (USTC) as a Professor in the School of Information Science and Technology. He is a Senior Member of IEEE and serves as an editor for the IEEE Transactions on Wireless Communications.

An Energy-Efficient Mechanism for Video Distribution

A short review for "Socially Aware Energy-Efficient Mobile Edge Collaboration for Video Distribution"

Edited by Jinbo Xiong

D. Wu, Q. Liu, H. Wang, D. Wu and R. Wang, "Socially Aware Energy-Efficient Mobile Edge Collaboration for Video Distribution," IEEE Transactions on Multimedia, vol. 19, no. 10, Oct. 2017.

With the rapidly increasing of wireless multimedia applications, the limited spectrum resources and the ever-increasing demand for videos pose a serious challenge to existing cellular network, e.g., base station (BS) overload, poor experience. To cope with the growing mobile data requirements, device-to-device (D2D) communication defined in 3GPP, was proposed to allow mobile devices in close proximity to transmit videos between each other, under the control of BS [1]. As a result, the network traffic load on BSs will be alleviated and video transmission delay can be effectively reduced [2].

However, applying D2D communications in video service still faces some severe challenges [3][4], and there are further complicated by the mobility of users, user attributes, unstable channel conditions, and high quality of experience (QoE) requirements. Particularly, video sharing typically introduces additional energy overheads for the transmitter, so that the sharing willingness needs to be considered. In general, the difference of social relationships among users leads to various transmission preferences, which will provide different service priorities for receiving users [5]. In addition, the movement of users makes D2D links exhibiting a discontinuous feature in both temporal and spatial domains, which may cause channel errors and packet losses in video transmissions.

In this paper, a user-attribute aware video distribution mechanism is proposed. Firstly, a virtual community is established, which exploits the coalition game based on the user's preference list to dynamically divide users into multiple communities. Besides, to take full advantage of the temporary link established between users, a grid-based clustering method is proposed to manage the video requesting users. In addition, by using the scalable video coding (SVC) technology [6], and with energy consumption as a constraint, the user's attributes are matched to the video stream characteristics and equipment capabilities. Specifically, to meet the user experience requirements, additional enhancement layer is further forwarded based on the logical relationship between users, namely user attributes are used to control encoded data forwarding. Therefore, it provides a certain degree of reliability and freedom for video transmission.

Thus, the authors' major contribution is to propose an energy-efficiency mechanism for video distribution. By exploit users' social characteristics and mobility to minimize the number of transmissions of BS, and improve the sharing willingness among users for video distribution.

An enormous amount of duplicate content requirement exists in the local service. In traditional video transmission, when multiple users access the same content, BS will transmit the content repeatedly, thus the burden of BS has increased. Therefore, the author proposes a distributed logical relation detection method by analyzing the similarity degree of user interest in different contents. Using coalition games, the users are dynamically divided into different virtual communities, then the users in units of clusters send request to BS.

Besides, a multicast mechanism based on the energy consumption of BS is employed. The highest link rate in the cluster is selected as the multicast rate to obtain the optimal cooperative cluster number, which is combined with the SVC technology for selectively receiving the enhancement layers among users. Subsequently, according to the geographical distribution and the residual energy of users, the set of cooperative transmission users can be reasonably established for video requesting users to complete the transmission of the video.

Furthermore, the data sharing typically incurs additional energy overheads, which reduces device operation time, and ultimately results in reducing the user experience. Therefore, to reduce the energy consumption, the SVC sharing mechanism based on the social characteristics of users is proposed, which can transmit the video data between users at various bitrates. The user can decide what to share in the local cache, which not only avoids redundant transmission, but also effectively reduces the transmission energy consumption of transmitters.

Extensive experiments demonstrate the improved performance of the proposed solutions. Simulation results show that the proposed mechanism can not only effectively alleviate the BS loads, but also improve the reliability and adaptability of video distribution.

In summary, the proposed distribution mechanism for video data distribution can relieve the current overload of BSs and improve user experience. In this proposed scheme, user ' s social characteristics and mobility are exploited to transfer some core network function to the network edge. By combining with SVC, the reliability and adaptability of video distribution are enhanced significantly.

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Jinbo Xiong, Ph.D, is an Associate Professor in the College of Mathematics and Informatics at Fujian Normal University. He received his M.S. degree in Communication and Information Systems from Chongqing University of Posts and Telecommunications, China, in 2006, and Ph.D. degree in Computer System Architecture from Xidian University, China, in 2013. His research interests include cloud data security, mobile data management, privacy protection, and Internet of Things. He has published papers in prestigious journals such as IEEE Internet of Things Journal, IEEE Transactions on Cloud Computing, and in major International conferences such as IEEE ICCCN, IEEE TrustCom, IEEE HPCC and IEEE ICPADS. He is a member of IEEE.

Paper Nomination Policy

Following the direction of MMTC, the Communications – Review platform aims at providing research exchange, which includes examining systems, applications, services and techniques where multiple media are used to deliver results. Multimedia includes, but is not restricted to, voice, video, image, music, data and executable code. The scope covers not only the underlying networking systems, but also visual, gesture, signal and other aspects of communication. Any HIGH QUALITY paper published in Communications Society journals/magazine, MMTC sponsored conferences, IEEE proceedings, or other distinguished journals/conferences within the last two years is eligible for nomination.

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Paper nominations have to be emailed to Review Board Directors: Qing Yang (qing.yang@unt.edu), Roger Zimmermann (rogerz@comp.nus.edu.sg), Wei Wang (wwang@mail.sdsu.edu), and Zhou Su (zhousu@ieee.org). The nomination should include the complete reference of the paper, author information, a brief supporting statement (maximum one page) highlighting the contribution, the nominator information, and an electronic copy of the paper, when possible.

Review Process

Members of the IEEE MMTC Review Board will review each nominated paper. In order to avoid potential conflict of interest, guest editors external to the Board will review nominated papers co-authored by a Review Board member. The reviewers' names will be kept confidential. If two reviewers agree that the paper is of Review quality, a board editor will be assigned to complete the review (partially based on the nomination supporting document) for publication. The review result will be final (no multiple nomination of the same paper). Nominators external to the board will be acknowledged in the review.

Best Paper Award

Accepted papers in the Communications – Review are eligible for the Best Paper Award competition if they meet the election criteria (set by the MMTC Award Board). For more details, please refer to http://mmc.committees.comsoc.org/.

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