MULTIMEDIA COMMUNICATIONS TECHNICAL COMMITTEE
http://www.comsoc.org/~mmc

MMTC Communications - Frontiers

Vol. 12, No. 2, March 2018

CONTENTS

Message from MMTC Chair

Dear MMTC friends and colleagues:

It is my pleasure to provide the message for the November issue of MMTC Communications-Frontiers. I joined the service for MMTC from 2010. Within the past few years, I have been witnessing the development and growth of MMTC. I am very proud of having been serving in MMTC and deeply enjoy working with MMTC team members for these years.

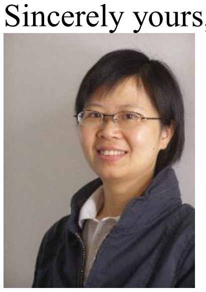
MMTC has fourteen interesting groups (IGs) focusing on different topics in the area of multimedia communications. In addition, MMTC has six boards in charge of award, MMTC Communications-Frontiers, membership, review, services and publicity, and advisor, respectively. I would like to take this opportunity to express my sincere appreciation to the directors and co-directors of boards, chairs and co-chairs of IGs, and the director of newsletters. Without your hard works and great efforts, MMTC cannot have such a success.

MMTC will hold TC meeting several times each year during the period of some main conferences such as ICC, GLOBECOM, ICME, etc. The next TC meeting will be hold at IEEE ICC 2018 at Kansas City, MO, USA. I would like to take this opportunity to invite all of you to join the incoming MMTC meeting.

MMTC provides very efficient channels to share, exchange, and discuss information and enhance the visibility of its members. MMTC also provides support for its members to upgrade your IEEE membership, to organize special issues, etc. The number of MMTC members is already above 1000. If you want to join the MMTC, please visit our Membership Board page at http://mmc.committees.comsoc.org/membership/. I have no doubt that you will benefit from being a member of MMTC.

Finally, MMTC Communications Frontiers provides the readers the timely update on the start-of-the-art development and hot research topics. I hope you will enjoy reading this issue of MMTC Communications Frontiers!

Sincerely yours,



Fen Hou
Vice Chair for Asia
Multimedia Communications Technical Committee
IEEE Communications Society

SPECIAL ISSUE ON Holographic Communications and Distributed Collaborations

Guest Editors: Yong Pei[1] and David Martineau[1§]

[1]*Wright State University, Dayton, Ohio, The United States*
[§]*Orthopedic Associates of SW Ohio, Dayton, Ohio, The United States*

yong.pei@wright.edu; dmartine79@gmail.com

Augmented reality (AR) offers the potential to augment a person's perception of subject matters and objects of interest to enhance the communications, interactions and collaborations between people. It has been recognized as a key technology toward solving talent and productivity problems in education and industries. AR technology allows a device to derive context about the particular physical environment and then overlay new and relevant information on top of it in real time, resulting in augmented perception by the user. Delivered via smart glasses, such as Google Glass or Microsoft HoloLens, AR provides a user instant access to, e.g., critical visual information, real-time updates, subject matter expertise, and step-by-step instructions on standard operating procedure, smoothing the integration between clinicians, patients and data in a smart, connected workspace. Recent adoption of AR in industries, such as manufacturing, transportation, healthcare industries and so on, though limited, has clearly demonstrated its potential to boost the service quality and labor productivity.

In this Special Issue, authors examine the latest progresses and trends in adopting, adapting and defining the AR technologies and their applications in industry practices and highlight their research findings and perspectives on the topic of holographic communications and distributed collaborations. The first contribution titled "Empathic Computing: A New Approach to Remote Collaboration" by M. Billinghurst describes the concept of Empathic Computing, a developing technology that warrants more future research. The author shows the current trends in human computer interaction, content capture and networking, particularly the latest research in emotion sensing and experiencing using Affective Computing and Virtual Reality. The paper also describe two Empathic Computing prototypes that use Augmented Reality and Virtual Reality to create new types of collaborative experiences that helps a person to better share what they are seeing, hearing and feeling with another person. The second contribution titled "Augmented Reality for Medicine: The New Frontiers" by A. Shivakumar and M. Vasoya shed light on the latest research and development efforts of applying AR technologies in the medical practices, particularly in Surgery, Combat Medicine, Mental Health, Medical Training and Education and Rehabilitation. The paper shows the clear demand of AR in medicine, presents some of the most novel and pathbreaking adoption of AR in medicine, and also some of the technical, financial, administrative hurdles for AR in medicine. The authors also stress the need for development and sharing of clinically validated models for higher accuracy and realism, through, e.g., open source AR platforms and assets for increased co-operation among developers and medical professionals in order to foster newer and innovative applications, better technical support and increased scaling of AR based software products in the medical market. The third contribution titled "A Survey of Holographic Communication and Distributed Collaboration Systems for Education" by P. Bender review the latest AR and VR based education technologies to improve learning and training outcomes, e.g., by providing individualized guidance to students or practitioners working in fields such as medicine and biology, or providing users with augmented representations of systems they are expected to learn and understand as a part of their training. The reported augmentation occurs as text, audio, images, video, virtual objects and may consist of information supplied in real time or as a pre-recorded data. The author concludes that VR and AR-based education applications just scratch the surface of what is possible given the relative youth of the technologies involved, especially when wearable devices are concerned. Finally, in their paper titled "Integration of product data management systems in Augmented Reality maintenance applications for machine tools", C. Kollatsch, et. al. describes the roles of AR in the ongoing future project Industry 4.0 that addresses new concepts for linking machine tools and mobile devices, information transparency as well as the field of technical assistance. In particular, the authors presented their latest research on the conjunction between the AR and the product data management (PDM) systems, a crucial problem for companies to use an AR maintenance application effectively in a productive environment.

Yong Pei, Ph.D. received his MS and Ph.D. degrees in EE from Rensselaer Polytechnic Institute in 1999 and 2002, and his BS degree in Electrical Power Engineering from Tsinghua University in 1996. He is an Associate Professor of Computer Science and Engineering at Wright State University, Dayton, Ohio, and directs the SMART lab with active research in areas of applied medical research, sensor system and networks, image and video sensory data processing, coding and networking, distributed collaborations and etc. His works not only result in significant advances in related research areas, but also lead to innovative solutions that address significant problems in the real-world, and are adopted in related practices.

David Martineau, MD received his medical degree from the University of Cincinnati College of Medicine, in 2005. Between 2005 and 2010 he completed his orthopedic surgery residency at the McLaren Regional Medical Center and in 2011 he completed his hand surgery fellowship at the Christine M. Kleinert Institute for Hand and Microsurgery in Louisville, Kentucky. He is currently an associate professor in the department of orthopedic surgery for Wright State University, associate professor for the Grandview Medical Center department of orthopedic surgery as well as the hand surgery fellowship. His research interests include clinical applications of augmented reality, live-action spatial mapping and motion analysis along with biomechanics. He is also a full-time practicing orthopedic hand surgeon at Orthopedic Associates of SW Ohio.

Empathic Computing: A New Approach to Remote Collaboration

Mark Billinghurst
University of South Australia, Mawson Lakes, Australia
Mark.Billinghurst@unisa.edu.au

***Abstract*— In this paper we describe the concept of Empathic Computing, which is developing technology that helps a person to better share what they are seeing, hearing and feeling with another person. We show how Empathic Computing aligns with current trends in human computer interaction, content capture and networking. We also show how it is related to research in emotion sensing and experiencing using Affective Computing and Virtual Reality. Finally we describe two Empathic Computing prototypes that use Augmented Reality and Virtual Reality to create new types of collaborative experiences that better help each person understand how the other person is feeling. Overall Empathic Computing provides an interesting new approach to remote collaboration with many directions for future research.**

Keywords—empathic computing; collaboration

INTRODUCTION

This paper describes the concept of Empathic Computing, a new approach to computer assisted collaboration, based on advances in human computer interaction, networking and content capture. In this paper we first review technology trends in each of these areas, then provide a definition of what Empathic Computing is, and examples of Empathic Computing systems, and finally discuss areas for future research.

The last 70 years have witnessed a significant change in how people interact with computers. The hard wired programming of the 1940's gave way to punch card and tape input (1960's), keyboard and screens (1970's) and the mouse driven WIMP interface (1980/90s). Current computer interfaces use a mixed of keyboard, mouse and touch. However there are also systems that use cameras, microphones and other sensors to allow natural interaction with voice and gesture. Research is currently being conducted on technologies for Brain Computer Interaction [ref] and responding to physiological cues, such as eye gaze and changes in heart rate. Overall the trend in human computer interaction has been from Explicit Input, where the user adapts to the machine, to Implicit Understanding, where the machine responds to natural user actions.

A second important technology trend is in networking. Nearly fifty years ago ARPANET was created, the first computer network based on the TCP/IP networking protocol. In the years since the network bandwidth has grown from a few hundreds of kilobits/second to gigabits/second. This has led to more natural collaboration when people initially could only communicate by text, can now using high bandwidth video conferencing and shared immersive virtual worlds. Companies such as Google and Facebook are exploring how to use balloons and autonomous planes to provide networking connectivity to everyone on earth.

A final trend is in content capture. From the 1830's the invention of photography meant that for the first time people could capture their surroundings. This was following by movies, live broadcast TV, internet streaming and now 360 video capture and sharing. Companies like Occipital are developing handheld scanners that enable people to capture the texture and geometry of their surroundings [1], while with Persiscope people can stream 360 video to remote locations [2]. In a few years it will be possible for a person to walk into a room and with a small handheld device capture and share a 3D digital copy of their surroundings live. In this way people will be able to perform experience capture of important events happening in their lives.

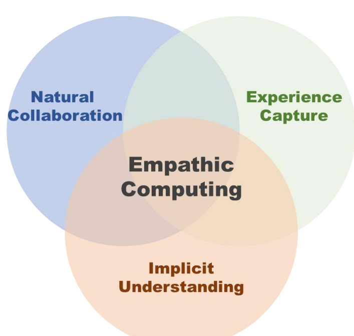


Fig. 1. Empathic Computing combines Natural Collaboration, Experience Capture, and Implicit Understanding [1].

Taken together the three trends of Implicit Understanding, Natural Collaboration, and Experience Capture converge in an area we call Empathic Computing. In the next section we describe this in more detail and then present some examples of using Empathic Computing for remote collaboration.

EMPATHIC COMPUTING

Psychologist Alfred Adler [3], famously described empathy as: *"..seeing with the eyes of another, listening with the ears of another, and feeling with the heart of another."*

We define Empathic Computing as: *Computing systems that help a person to share what they are seeing, hearing and feeling with another person.*

There are many examples of collaborative systems that are designed to connect remote people together, or even to provide a view of one person's workspace to another. For example, a wearable camera and computer can be used to live stream what one person is seeing to a remote collaboration [4], enabling the remote collaborator to feel that he or she is seeing through the eyes of the local user. However Empathic Computing goes beyond this by enabling one person to share their feelings with another, and so create a greater sense of empathy between the two users.

From a technical perspective Empathic Computing has its roots in emotion, and in particular the three aspects of sensing, experiencing and sharing emotion.

There are a wide range of technologies which can be used to sense emotion. Since the 1990's the field of Affective Computing [5] has emerged with a focus on developing systems that can recognize human affect or emotion. There have been many systems developed that can infer affect from face expression, vocal cues, or even heart rate and other physiological measures. Research in Affective Computing has developed many reliable methods of detecting emotion, however in most cases these are single user systems, where a computer responds to a user's emotional state. For example, Rekimoto has developed applications that recognize when a person smiles and will only work when a user smiles at them [6].

A second area of related work is technology for creating emotional experiences. Over the years, there have been many technologies used to evoke emotion, from record players, to film, television and computer games. The most recent example of Virtual Reality (VR), technology that immerses a user in a completely digital environment. Chris Milk called Virtual Reality ".. the ultimate empathy machine", and went on to develop some highly emotional VR 360 film experiences, such as allowing people to visit a refugee camp in Syria or slum in Liberia [7]. VR filmmaker Nonny de la Peña also developed some immersive 3D graphic VR experiences showing a terrorist bomb blast in Syria or homelessness in Los Angeles [8]. There are also many other examples of people using VR to transport viewers into different locations and circumstances to create an emotional experience, or increase empathy. However in this case the VR experiences are pre-recorded or pre-made and don't create a live connection between people and the source material.

With Empathic computing we are interested in the third aspect of being able to share emotional experiences live. As mentioned there has been a significant amount of research in Affective Computing and how to sense emotion, and many people researching how to use technology to create emotion and empathy, but until now there has been relatively little, if any, research on sharing emotional experiences live.

In our research we are exploring how to use technologies such as wearable computing, computer vision, Augmented and Virtual Reality, and physiological sensors to enable a person to see through another's eyes, hear what they are hearing, and understand what they are feeling, to create a truly empathic experience.

In the next section we describe two examples of Empathic Computing interfaces that we have developed that provide early prototypes of the systems that could be developed in the future to create new types of collaborative experiences.

CASE STUDIES

In the Empathic Computing Laboratory at the University of South Australian we have been developing and testing several different types of Empathic Computing experiences. This section describes two of them; Empathy Glasses and Empathic Virtual Reality Spaces.

EMPATHY GLASSES

The Empathy Glasses were a new type of Augmented Reality wearable teleconferencing system that allows people to share gaze and emotion cues. This section provides a brief overview of the technology, they are described in more depth in [9].

The Empathy Glasses are a head worn system that is designed to create an empathic connection between remote collaborators. They combine the following technologies together (1) wearable facial expression capture hardware, (2) eye tracking, (3) a head worn camera, and (4) a see-through head mounted display (see figure 2).

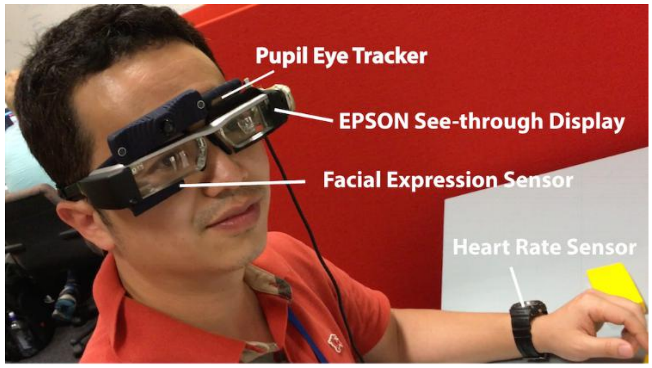


Fig. 2. Empathy Glasses, showing sensors used in the system.

In a traditional wearable system the user often had a head worn camera and display that enables them to stream a live video of what they are seeing to a remote collaborator and get feedback from the collaborator in their display. However the remote collaborator does not know exactly where the person is looking, or how they are feeling.

The Empathy Glasses adds the AffectiveWear technology to a see-through head mounted display. The AffectiveWear glasses are a pair of glasses that can measure the wearers' facial expression by using photosensors to measure the distance from their glasses to their skin [10]. In the Empathy Glasses we take the photosensors from the AffectiveWear device and mount them around an Epson Moverio BT-200 display.

The second addition to the BT-200 is a Pupil Labs eye-tracker [11]. This is a pair of small cameras and infrared illuminators mounted just below the eye-line. These cameras and the Pupil Labs software can track the eye gaze up to 60Hz and to fraction of a degree.

Taken together this technology allows the remote user to not only see video from the local user's head worn camera, but also see an eye-gaze point showing exactly where they are looking in the video and have an indication of their facial expression. In this case the remote user views this information on a desktop interface (see figure 3). They are also able to use mouse input to provide pointer information back to the local user, enabling two way communication.

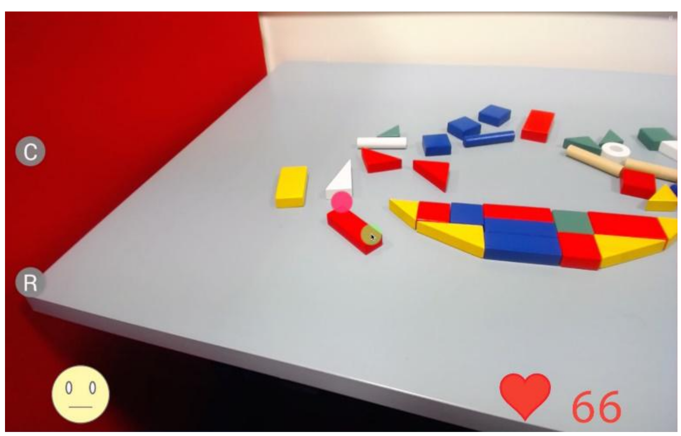


Fig. 3. Remote Expert Desktop View – show local user gaze, face expression and heart rate. The green dot is the remote expert's mouse point, and the red dot above the local user's gaze point.

The main interesting aspect of the Empathy Glasses is that they change the nature of remote collaboration. In a traditional remote collaborative system, the remote user will ask the local user to perform a task and then wait while they do it. So there is a need for explicit communication between the two parties. With the Empathy Glasses the remote user can watch the eye gaze patterns of the local user and know if they are paying attention. People generally look at objects before they interact with them, so the remote user will know if the local user is about to pick up the

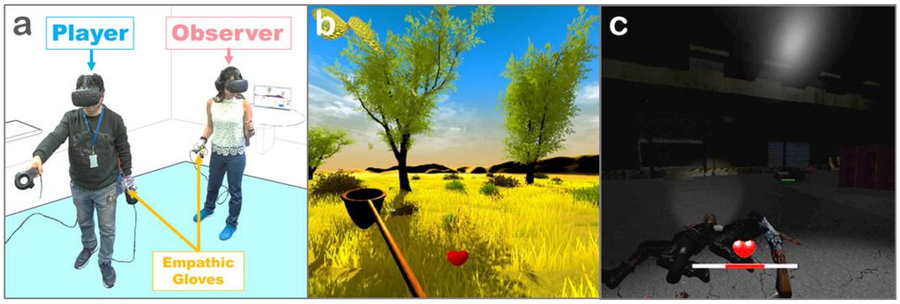


Fig. 4. a) Shared VR study setup showing player and observer co-located in the same space, b) calm butterfly game, c) scary zombie game.

w
rong object. In this way eye-gaze provide implicit cues, and the nature of the teleconferencing interface is changed completely.

As reported in [9] we conducted a user evaluation with the system comparing collaboration with and without eye-gaze and pointer sharing. Users reported that see the eye-gaze of their partner was very valuable and helped to create a deeper sense of Social Presence compared to collaboration without sharing eye-gaze. They also felt that is was very valuable to have a shared pointer from the remote user. This work indicated that sharing both gaze and emotional cues could significantly enhance user experience in collaboration and provided an early evidence supporting the pursuit toward Empathic Computing.

EMPATHIC VIRTUAL REALITY SPACES

Apart from sharing emotions, we also explored sharing more basic physiological cues. For this, we created an immersive collaborative VR experience where multiple players were co-located sharing the same position in the virtual environment but had an independent head orientation with an added physiological cue of heart-rate, see Figure 4. More details of the system is contained in the full paper [12].

One participant had the role of the Player who was supposed to interact with the VR content, while the other participant was the Viewer, who could see the VR scene from the Player's position, but couldn't interact with any of the content. The Viewer is able to freely look around, which reduces the feeling of simulator sickness.

The heart rate was captured using a special Empathic Glove that had an Arduino board mounted on it connected to a heart rate sensor in one of the glove finger tips, and GSR sensor in another figure (see figure 5).

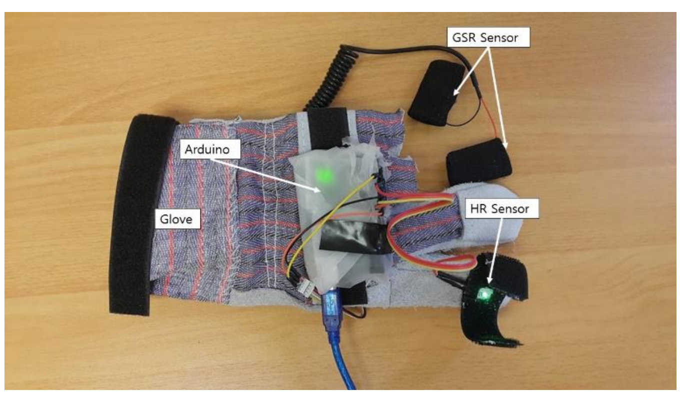


Fig. 5. Empathy Glove, showing heart rate and GSR sensors mounted on the figure tips and connected to Arduino sensor.

The motivation was to explore how using a shared viewpoint and simple physiological cue, such as heart-rate, can increase the feeling of connectedness and enhance the experience between a player and observer in a collaborative VR. For our exploratory study, we created two games with different contexts, one was a calm butterfly catching game, and the other, a scary zombie shooting game as shown in Figure 4b and 4c. The butterfly catching game was designed to be relaxing, while the Zombie game is scary.

We shared the player's heart-rate to the observer through visual and audio cues. The heart rate sensor was used to record the Player's heart rate which was then played back to the Viewer as a heart beating sound, and they could also see a beating heart icon beating at the same rate of their partner.

In a user study with the system [12] we found that the gaming experiences had a strong influence over the heart-rate cue, where heart-rate was overall preferred subjectively, but the effect was not significant and yielded low statistical power with the current setup and the number of participants that we had. We believe that by combining the information from the physiological interface and the context of the event in the game, the player states of mind could potentially be empathized by the observer.

CONCLUSION

In this paper we have described the concept of Empathic Computing, namely technology that helps a person to share what they are seeing, hearing and feeling with another person. As was shown in the introduction, Empathic Computing occurs at the convergence of technology trends towards Implicit Understanding, Natural Collaboration, and Experience Capture, and so there are a number of emerging technologies that can be used to build Empathic Systems.

Empathic Computing also builds off previous work in Affective Computing and AR and VR. Previous research has mostly been design for single user emotion recognition, or experiencing pre-recorded immersive emotional experiences. The main difference that Empathic Computer offers is sharing live experiences.

The paper then showed how two prototypes of Empathic Computing systems exploring different elements of shared experiences. With the Empathy Glasses technology was used to share non-verbal cues not normally present in shared workspace remote collaboration. The Empathic Virtual Reality Spaces explored if sharing emotion in VR could create a heightened emotional experience and increase the understand of the Viewer for what the Player was experiences.

The results from these systems is encouraging, however this research is just beginning. More work needs to be done on how to reliably measure affect and emotion, and how to represent emotional state between users. We also need to explore how AR and VR technology can be used to create a greater variety Empathic Computing experiences. Finally there is a lot more user testing to be done to validate the concept of Empathic Computing and help use it to create more rewarding remote collaboration experiences.

REFERENCES

[1] Occipital Website: https://occipital.com/
[2] Periscope live 360 video streaming: https://www.pscp.tv/
[3] J. Clark, "Empathy and Alfred Adler: An Integral Perspective," The Journal of Individual Psychology, vol. 72, pp. 237-253, 2016.
[4] Fussell, S. R., Setlock, L. D., Yang, J., Ou, J., Mauer, E., & Kramer, A. D. (2004). Gestures over video streams to support remote collaboration on physical tasks. Human-Computer Interaction, 19(3), 273-309.
[5] Picard, R. W. (1995). Affective computing.
[6] Tsujita, Hitomi, and Jun Rekimoto. "Smiling makes us happier: enhancing positive mood and communication with smile-encouraging digital appliances." *Proceedings of the 13th international conference on Ubiquitous computing*. ACM, 2011.
[7] Herson, B. (2016). Empathy Engines: How Virtual Reality Films May (or May Not) Revolutionize Education. *Comparative Education Review, 60(4),* 853-862.
[8] Sánchez Laws, A. L. (2017). Can Immersive Journalism Enhance Empathy?. *Digital Journalism,* 1-16.
[9] Masai, K., Kunze, K., & Billinghurst, M. (2016, May). Empathy Glasses. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*(pp. 1257-1263). ACM.
[10] Masai, K., Sugiura, Y., Ogata, M., Suzuki, K., Nakamura, F., Shimamura, S., ... & Sugimoto, M. (2015, July). AffectiveWear: toward recognizing facial expression. In *ACM SIGGRAPH 2015 Emerging Technologies* (p. 4). ACM.
[11] Pupil Labs Website: https://pupil-labs.com/
[12] Dey, T. Piumsomboon, Y. Lee, and M. Billinghurst, "Effects of Sharing Physiological States of Players in a Collaborative Virtual Reality Gameplay," presented at the Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Denver, Colorado, USA, 2017.

Mark Billinghurst is Professor of Human Computer Interaction at the University of South Australia in Adelaide, Australia. He earned a PhD in 2002 from the University of Washington and researches innovative computer interfaces that explore how virtual and real worlds can be merged, publishing over 350 papers in topics such as wearable computing, Augmented Reality and mobile interfaces. Prior to joining the University of South Australia he was Director of the HIT Lab NZ at the University of Canterbury and he has previously worked at British Telecom, Nokia, Google and the MIT Media Laboratory. His MagicBook project, was winner of the 2001 Discover award for best entertainment application, and he received the 2013 IEEE VR Technical Achievement Award for contributions to research and commercialization in Augmented Reality. In 2013 he was selected as a Fellow of the Royal Society of New Zealand.

Augmented Reality for Medicine: The New Frontiers

Ashutosh Shivakumar and Miteshkumar M. Vasoya
SMART Lab, Wright State University, Dayton, Ohio, USA

1. Introduction

There is a strong need to bridge the gap between 3-dimensional physical world and the 2-dimensional information space such as newspapers, books, images on computers and television, to better harness the enormous potential of vast amounts of data [1]. Augmented Reality (AR) is a technology that improves our perception of reality by transforming volumes of 2-dimensional data into 3-dimensions in the form of holograms or animations by overlaying them on the real objects found in the physical environment. By superimposing the 3-dimensional holograms, images or animations onto the real world, it brings this information into context by allowing the user to interact with it.

Today, AR has its applications in a wide range of areas like navigation: heads up display, collision warning in automobiles, occupational training and maintenance: wearable AR devices help factory workers by overlaying service instructions on machines for maintenance, hospitals and medical classrooms: for visualizing human anatomy and understanding physiology and in operation theaters for aiding surgeons with critical details of the patient's anatomy. With investments in AR estimated to reach 60 billion USD in 2020 [1], there is little doubt that AR is poised to be the dominant technology in this "Information Age".

There are different types of AR devices that can be used based on the specific application. According to our extensive literature survey we have mainly classified this wide spectrum of devices into: 1. AR capable phones and tablets: like Google's Project Tango, Asus's ZenFone AR and introduction of ARkit from Apple to enable development of Augmented reality applications, 2. Projection based AR: MagicLeap, Microsoft's Kinect 3. AR and mixed reality capable Optical See – Through Head Mounted Displays (OST - HMD) that include devices like Meta Space Glasses and Microsoft HoloLens.

However, we have limited our literature review survey to OST – HMD based AR devices because they offer excellent virtual object overlay capabilities without losing the real-world view context and provide hand-free operations and portability.

2. Objective

Our focus through this paper is to explore the new frontiers of AR applications in the medical domain. Patient safety is of paramount importance in medical practice. All medical procedures and learning is designed to achieve zero margin for error. This requires proficiency and efficiency at various stages learning and practice, ranging from a student's thorough understanding of complex physiological systems and mastery in visualizing the spatial relationship of anatomy, a surgeon's undivided attention in the operating Room and physiotherapist to design effective exercises to help in patient recovery. Devices like the HoloLens allow the interventionist to manipulate the three-dimensional holographic information in real time to obtain instantaneous feedback about the patient. Thus, we strongly believe that AR has a significant potential in medical domain. Consequently, we have spent significant efforts in creating awareness of some of the current state of the art applications of Augmented reality in the medical domain, attention is paid to the recent, specifically after 2016, applications of Head Mounted Display based AR devices in the medical domain.

Through this review paper we have tried to discover the following topics:

1. The recent trends of application of AR, particularly holographic computing enabled OST-HMD based devices in the medical domain.

2. The current barriers and recommendations to overcome them.

3. Method

We set about the task of unearthing the current trends of the application of AR in the medical domain by conducting a thorough review process of research papers and journal articles from PubMed, with greater focus on research after 2016 and search terms related to augmented reality, holographic computing, Microsoft Hololens. The reason for our emphasis on this timeline can be ascribed to the significant development of applications on this platform after its introduction in the year 2016.

Based on the trends identified in our literature survey, we have broadly classified the augmented reality applications in the medical domain into the following subdomains: 1. Surgery 2. Combat Medicine 3. Mental Health 4. Medical Training and Education 5. Rehabilitation.

4. Results

AR in Surgery:

All authors in the research articles concerning applications of AR in medical visualization agree on the difficulty for surgeons to compare and analyze two dimensional images on the monitor with the actual surgical field and to simultaneously operate on the patient at hand. To overcome this hindrance due to Gaze disruption [2], they have all suggested applications of AR catering to augmentation of virtual images in real scene in real – time, contributing to an immersive experience for the surgeon. AR helps in pre – operative planning and intra – operative visualization and manipulation of information for better decision-making in the OR.

In the field of image guided surgery and imaging, Kuhlemann, et al. [3] have proposed a Hololens based holographic visualization system which aligns patient's vascular tree hologram with the body of the patient creating an illusion of seeing inside the patient. Although, this system was tested on a phantom, it has a significant potential to visualize the navigation of surgical tools in the minimally invasive surgery of Endovascular stenting of aortic aneurysm. Mojica, et al. [4] have presented an AR/MR system that uses the HoloLens for preoperative and intraoperative visualization of MRI data. This system displays the 3-D holographic vasculature tree and the corresponding 2D MRI slice window for easier comprehension. The most interesting aspect of this prototype is its capability to utilize the manipulation of the holographic visualization as an input to make changes to the 2D image visualization from the MRI scanner. Although this research lacked sufficient trials in the actual OR it is a refreshing attempt to utilize the spatial 3-D knowledge provided by the Hologram for preoperative planning of surgery and intraoperative decision making in real time. The application also features a "walker" mode to scale the holographic scene to the height of the operator to provide a different perspectives and better resolution of structures closer together. Further, it is worth noting the projection based AR setup proposed by Tabrizi and Mahvash [5]. Their implementation is a projection based technique which projects the 2D image on the head of the patient and uses fiducial markers around the tumor for registration. Further, it is used to plan the skin incision for craniotomy and visualize tumor borders on the brain surface. The authors further claim that this system provides ergonomic advantage as there is no HMD in the direct view of the surgeon. However, it is commendable that they have validated this technique in live surgical scenarios with 5 patients but agree to the fact that it would need additional trials to be used as a medical grade product. It would be interesting to see how they would address the problem of real – time identification of deep tumor borders after brain shift.

AR in Combat Medicine:

Combat injuries require effective and rapid treatment. They are characterized by polytrauma (injuries affecting multiple organs) and inability to evacuate soldiers to a hospital due to austere and chaotic battlefield conditions. Immediate and effective spot resuscitation and prehospital care is critical as it is estimated that 90% of deaths occur before the wounded can be transferred to the nearest medical station [6, 7].

Hence, 1. Effective training of combat medics to prevent disintegration of critical skills 2. Equipping combat medics with appropriate auditory, visual and tactile cues in real-time battlefield resuscitations. 3. Availability of the expertise of surgeons physically located in civilian hospitals at the emergency medical stations are necessary.

The authors of the research articles reviewed in this section propose that AR can be the means to the above necessities. Andersen, et al. [6] have proposed a tablet based AR system called STAR (System for Tele mentoring with AR), where a tablet is suspended between the local surgeon and the patient and the remote surgeon can make annotations to live recorded video of the patient on the tablet for the benefit of the local surgeon. This novel idea does not come without pitfalls, there is a potential that expert guided annotations would be static and unchanged due to disruption in internet connectivity. To overcome this difficulty, they have anchored the annotation with the object. However, the small form factor of the tablet not letting the remote surgeon examine the entire body of the patient coupled with issues of latency and lack of security encryption need to be solved if the AR system must become a mainstream product. Further, this study is a good representation of the confluence of the advantages of AR, telemedicine to solve the drawbacks in combat medicine.

Further, Wilson, et al. [7] have built a goggle based AR system to improve the accuracy of combat medics in placing a large bore catheter to release tension pneumothorax. In this pilot study, two groups of students with little or no clinical experience in invasive medical procedures were instructed to perform the decompression of tension pneumothorax. According to the authors the group with the AR goggles performed better due to visual and audio cues provided by the AR goggles than the group without AR assistance. Thus, the authors have concluded that AR fills the gap of failed recall of critical combat training by providing situational and contextual awareness. However, the above trial was performed in the safe environs of a university, so it would be noteworthy to analyze the performance and the ergonomics of the system in a battle field scenario.

AR in Mental Health:

Autism Spectrum Disorder affects about 1 in 68 children and over 3.5 million people in the United States. Autism Spectrum Disorder (ASD) is characterized by social skill impairments [9]. People with ASD have shown limited ability in facial emotion processing [10]. This could be one of the main contributing factors for their difficulties in social communication. Consequently, the general population could feel a sense of "disconnection" due to the inability of autistic patients to reciprocate emotions [11] and some of the adverse effects of this could be: 1. The inability of parents to have an emotional connection with their children; 2. Decrease in employment rate of autistic people, due to their socio-communicative skill deficit.

To help solve the problems pertaining to "gaze indifference" and "facial emotion recognition impairment", the main characteristics of autistic patients, the following authors have proposed an AR based solution primarily focused on Head Mounted Displays.

In their report, Liu, et al.[17], have used an Augmented Reality Glasses game based solution to teach children and adults emotion recognition, face directed gaze and eye contact. They have proposed gamified applications called FaceGame and EmotionGame to help autistic patients recognize face and emotions. According to the authors, FaceGame helps in solving the problem of "gaze indifference", it is essentially a face recognition algorithm that takes inputs from the real – time camera feed from the AR glasses and overlays a cartoon face to engage the user. Longer the user or wearer stares at the person's face, the game awards more points to the autistic user, thereby encouraging the patient to observe the face for a longer duration. To help with facial emotion recognition, the authors have proposed EmotionGame. Emotion game uses artificial intelligence coupled with facial emotion recognition. The game assesses emotion from the detected human faces and presents the user with emoticon choices. These applications were tested on two male ASD patients aged 8 and 9 years and decreased symptoms was evidenced by means of improved aberrant behavior checklist at 24 – hour post intervention. However, a few drawbacks of this study include the fact that the number of test subjects in the trials were just 2 in number and of same age and sex and the accuracy metric of the emotion recognition software was not discussed in detail.

Further, Xu, et al. [18] have proposed a wearable AR Glass platform called "LittleHelper" to provide a customized solution for individuals with ASD to improve their social communication during job interviews. The face – detection algorithm uses the camera on the google glass to provide visual feedback of the interviewer. When the face is off-center, to direct the user's head pose to reestablish proper eye – gaze, an arrow is shown directing towards the face of the interviewer. To help with the modulation of speech volume and enable socially acceptable speech, the Root Mean Square (RMS) value of the audio signals are taken as an input, the ambient noise level is considered and the distance between the interviewer and the subject is considered through face – detection of the glasses. No clinical tests were conducted to prove the validity of the device and the results shown are based on expert feedback.

AR in Medical Training and Education:

Medical training or learning is work place based learning where students are exposed to actual patients as part of their internships or postgraduate residency training. This provides an excellent opportunity for the students but is too risky from a patient's perspective. Any unintentional error on the part of the student in the process of learning could directly affect the health of the patient.

Moreover, medical learning is a complex, visual, tactile, adaptive and cooperative process as it requires both the instructor and the student to hold the same perspective when the analyzing the complicated visual aspects of an organ system or understanding its physiology. Further, performance of medical procedures requires adaptation, cooperation and communication, which can be practiced in the safety of a classroom from a first-person point of view. This equips the student with greater confidence to experiment and learn by trial and error [8].

The articles reviewed in this section offer valuable insights into adopting holographic AR based training tools into medical classroom learning. It is notable that Case Western Reserve University, Cleveland, Ohio in a partnership with Microsoft have shown the implementation of the Microsoft HoloLens into learning of complex physiological and anatomical concepts in human anatomy [12]. Further, LucinaAR a Microsoft HoloLens based application created by CAE Healthcare projects the various stages of childbirth onto the mother manikin and simulates a real – life childbirth scenario to the students for training [13]. Another novel holographic HoloLens based application, "HoloPatient" is demonstrated at the University of Canberra, Canberra, Australia where second – year nursing students practice skills of "Visual assessment and Documentation" by observing holographic patients projected in classrooms. Additionally, Rochlen, et al. [15] have proposed an AR glasses based AR trainer that provides a first-person point of view based training for medical students for needle insertion in central venous catheter (CVC) placement. The participants could initially train by viewing the projected internal anatomy of the sternocleidomastoid muscle and clavicle, revealing the apex of the triangle as the target of needle insertion. According to the authors, majority of the 40 participants, mainly medical students and personnel belonging to different years of expertise reported that the "ability to view the internal anatomy" was useful.

AR in Rehabilitation:

Stroke is a condition caused due to interruption of blood supply or hemorrhage into the brain tissue, resulting in interruption of blood supply to the brain. This causes motor impairments resulting in hemiplegia or paralysis affecting the stroke survivors' gait, or the ability to walk.

The authors in these reviewed articles believe that there is a strong need for a personal, easily accessible rehabilitation system. This proposition is made based on the following shortcomings of the traditional (non - computer) based rehabilitation techniques: 1. Most of the rehabilitation centers and hospitals are in urban areas, so it is difficult for stroke survivors in rural areas to travel to these urban centers. 2. Discontinuation of exercises and disinterest among stroke survivors, contributing to negligible improvement in their symptoms.

In this direction of research, Mills, et al. [19] have proposed a Microsoft HoloLens based AR therapy system for gait rehabilitation of lower amputee patients or debilitating stroke – recovering patients. This system overlays a virtual obstacle course, perceived by the Microsoft HoloLens, on the physical world. The clinician can vary the levels of difficulty of the obstacle courses based on the improvement shown by the patient, as evidenced by the inertial sensor data. Although, there is no clinical validation for this system, it is an excellent representation of advantages of gamification of mundane physiotherapy exercises. Another, notable application of the HoloLens in therapy is the "Retrain the Brain" project started by a Microsoft Employee. It is a multisensory approach to strengthen the neurological communication within the brain to improve the overall symptoms of patients suffering from "Myoclonus Dystonia" a condition that contributes to uncontrollable muscle spasms due to misfiring of the brain. The main idea of this therapy is to retrain the brain by tricking it with illusions. In this project, the HoloLens provides this illusion. With repeated usage of the device the learned connections within the Brain increases, consequently the affected neural pathways get strengthened.

5. Current Limitations for AR adoption in Medicine

Financial Limitations

Augmented Reality and Holographic computing is still in its infancy. This is evidenced from the fact that the Microsoft HoloLens, the most popular AR device is in its Developer version and not in mass market. Despite the theoretical studies and prototypes built by startups and industries, the financial investment in AR and particularly its application in Medical Domain is in its infancy. But it is worth noting that hospitals are increasing budgets for clinical simulation centers and purchase of AR equipment [16].

Technical Limitations

Technical development of AR based applications require clinically validated models for higher accuracy and realism. Further, open source AR platforms must be developed for increased co-operation among developers. This could foster newer and innovative applications, better technical support and increased scaling of AR based software products in the market.

Clinical Organization Issues

One of the main factors impeding the usage and validation of AR based devices in hospitals is the inability to use the secure hospital infrastructure for these devices. Most of Electronic Health Records of the patients are stored and transferred using secure networking infrastructure. To access these records the AR devices should be on the same network as the servers hosting this information. The security aspect of the AR applications handling this information prevents the agencies from permitting validations and actual uses of these devices. Platform incompatibility of running AR based software applications alongside hospital applications and complex public tender processes and lengthy hospital board decision making processes could be barriers to the easy adoption of healthcare devices [16].

Other Issues

Although this review paper has presented some of the most novel and pathbreaking adoption of AR in the medical domain, it is difficult to ignore the lack of actual clinical trials and validation of AR based systems in hospitals with actual patients. There is a strong need for randomized control trials for mainstream adoption of AR by healthcare providers. Further, due to infancy of the adoption of AR in medical industry, currently there is no clear insurance policy defined for its adoption, but we strongly believe that this will improve with increase in scale of adoption [16].

6. Conclusion

The various research works reviewed through this paper are clear indication that patient safety and recovery can be significantly improved through Augmented Reality, one of the most promising technologies that help simplify complex medical practices through visualization and presentation of data in the actual practice context. Yet, significant efforts by the regulatory agencies, healthcare providers and receivers are still needed to make healthcare simple, personalized and cost – effective through AR.

References

[1] E. Porter, M., & E. Heppelmann, J. (2017, November 1). A Manager's Guide to Augmented Reality. Retrieved February 28, 2018, from https://hbr.org/2017/11/a-managers-guide-to-augmented-reality

[2] Tepper, O. M., Rudy, H. L., Lefkowitz, A., Weimer, K. A., Marks, S. M., Stern, C. S., & Garfein, E. S. (2017). Mixed Reality with HoloLens: Where Virtual Reality Meets Augmented Reality in the Operating Room. *Plastic and Reconstructive Surgery*, *140*(5), 1066–1070. https://doi.org/10.1097/PRS.0000000000003802

[3] Kuhlemann, I., Kleemann, M., Jauer, P., Schweikard, A., & Ernst, F. (2017). Towards X-ray free endovascular interventions #8211; using HoloLens for on-line holographic visualisation. *Healthcare Technology Letters*, *4*(5), 184–187. https://doi.org/10.1049/htl.2017.0061

[4] Mojica, C. M. M., Navkar, N. V., Tsekos, N. V., Tsagkaris, D., Webb, A., Birbilis, T., & Seimenis, I. (2017). Holographic Interface for three-dimensional Visualization of MRI on HoloLens: A Prototype Platform for MRI Guided Neurosurgeries. In *2017 IEEE 17th International Conference on Bioinformatics and Bioengineering (BIBE)* (pp. 21–27). https://doi.org/10.1109/BIBE.2017.00-84

[5] Besharati Tabrizi, L., & Mahvash, M. (2015). Augmented reality–guided neurosurgery: accuracy and intraoperative application of an image projection technique. *Journal of Neurosurgery*, *123*(1), 206–211. https://doi.org/10.3171/2014.9.JNS141001

[6] Andersen, D., Popescu, V., Cabrera, M. E., Shanghavi, A., Mullis, B., Marley, S., … Wachs, J. P. (2017). An Augmented Reality-Based Approach for Surgical Telementoring in Austere Environments. *Military Medicine*, *182*(suppl_1), 310–315. https://doi.org/10.7205/MILMED-D-16-00051
[7] Wilson, K. L., Doswell, J. T., Fashola, O. S., Debeatham, W., Darko, N., Walker, T. M., … Weaver, W. L. (2013). Using Augmented Reality as a Clinical Support Tool to Assist Combat Medics in the Treatment of Tension Pneumothoraces. *Military Medicine*, *178*(9), 981–985. https://doi.org/10.7205/MILMED-D-13-00074
[8] Kamphuis, C., Barsom, E., Schijven, M., & Christoph, N. (2014). Augmented reality in medical education? *Perspectives on Medical Education*, *3*(4), 300–311. https://doi.org/10.1007/s40037-013-0107-7
[9] Baio J; Developmental Disabilities Monitoring Network Surveillance Year 2010 Principal Investigators; Centers for Disease Control and Prevention (CDC). Prevalence of autism spectrum disorder among children aged 8 years: Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2010. *MMWR Surveill Summ* (2014) 63(2):1–21.
[10] Tanaka JW, Sung A. The "eye avoidance" hypothesis of autism face processing. *J Autism Dev Disord* (2016) 46(5):1538–52. doi:10.1007/ s10803-013-1976-7
[11] Association AP. *Diagnostic and Statistical Manual of Mental Disorders (DSM- 5®)*. Arlington: American Psychiatric Association Publishing (2013)
[12] Case Western Reserve, Cleveland Clinic Collaborate with Microsoft on Earth-Shattering Mixed-Reality Technology for Education. (n.d.). Retrieved March 12, 2018, from http://www.case.edu/hololens/
[13] HoloLens Can Now Simulate Childbirth to Train Medical Students. (n.d.). Retrieved March 12, 2018, from https://hololens.reality.news/news/hololens-can-now-simulate-childbirth-train-medical-students-0182126/
[14] Baker, E. (2017, October 7). Meet the patients happy for nursing students to take their time. Retrieved March 12, 2018, from http://www.canberratimes.com.au/act-news/university-of-canberra-nursing-students-treat-hololens-hologram-patients-20171002-gysmab.html
[15] Rochlen, L. R., Levine, R., & Tait, A. R. (2017). First Person Point of View Augmented Reality for Central Line Insertion Training: A Usability and Feasibility Study. *Simulation in Healthcare : Journal of the Society for Simulation in Healthcare*, *12*(1), 57–62. https://doi.org/10.1097/SIH.0000000000000185
[16] Key Challenges to Adoption of VR/AR for Healthcare. (n.d.). Retrieved March 12, 2018, from http://www.thevrara.com/blog2/2017/6/10/key-challenges-to-adoption-of-vrar-for-healthcare
[17] Liu, R., Salisbury, J. P., Vahabzadeh, A., & Sahin, N. T. (2017). Feasibility of an Autism-Focused Augmented Reality Smartglasses System for Social Communication and Behavioral Coaching. *Frontiers in Pediatrics*, *5*. https://doi.org/10.3389/fped.2017.00145
[18] Xu, Q., Cheung, S. c S., & Soares, N. (2015). LittleHelper: An augmented reality glass application to assist individuals with autism in job interview. In *2015 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA)* (pp. 1276–1279). https://doi.org/10.1109/APSIPA.2015.7415480
[19] Craig, M., Ravinal E., Aroyan G., Nothnagle S. Augmented Reality System for Gait Rehabilitaition of Amputee and Stroke Patients

Ashutosh Shivakumar is a Ph.D. student majoring in Computer Science at SMART Lab, Wright State University, Dayton, Ohio. He received his Bachelor of Engineering in Electronics and Communication from Visveswaraya Technological University, Belgaum, India in 2014, Master of Science in Computer Engineering from Wright State University, Dayton, Ohio, United States in 2017. His current research interests include Deep Learning based speech analytics, Augmented Reality, Smart Mobility and Smart City based concepts.

Miteshkumar M. Vasoya is a Ph.D. student, majoring in Computer Science and Engineering and Graduate Research Assistant at SMART Lab, Wright State University. He received his Bachelor's degree from Gujarat Technological University, India, in 2014. His research interests include augmented reality applications in medical and industry domain, assisted technologies, computational design and optimization applications.

A Survey of Holographic Communication and Distributed Collaboration Systems for Education

Paul Bender
Ohio Dominican University
benderp2@ohiodominican.edu

INTRODUCTION

Virtual and Augmented reality are terms that have entered the popular lexicon to describe techniques of presenting 3dimensional information to users of computing systems. Advances over the last few years have brought out products such as the Microsoft Hololens [1], Glass X [2], and the Occulus Rift [3]. The technology brings many possible applications within reach of both individuals and institutions. This articles provides a review of some of the applications that have been proposed for these technologies with a focus on cooperative work and learning.

We can take the idea of the Holodeck introduced in *Star Trek:The Next Generation* as inspiration for some of the work we wish to accomplish [4]. The idea behind the Holodeck is a completely immersive collaborative 3D environment where multiple people can interact with virtual objects. While this obviously is a fantasy, it provides an aspirational goal for much of the work we do.

The rest of this paper takes a look at some early systems that allow remote collaboration, then moves on to types of systems used in modern literature and applications in K-12 education, higher education, and professional training.

EARLY SYSTEMS

Examples of systems used for distributed collaboration date back several decades. For purposes of this article, I have selected a few examples from the late 1990s and early 2000s to illustrate the progress made in this area.

In [5] the authors constructed a distributed virtual microscopy system system where real time video from an electron microscope can be shared with remote users. As part of the work, the authors also discus the process of building a 3D reconstruction an object from a holographic image of the object constructed by an electron microscope. This reconstruction can then be distributed to users.

In [6], the authors produced a system by which users could interact with a shared physical interface, called a Tangible User Interface, consisting of real objects in a distributed fashion. While this interface design consisted of physical, rather than virtual, objects, the ideas presented are very much the same as those we present when thinking about virtual environments. Much as we might collaborate by manipulating virtual objects, users of the system in [6] could manipulate a physical object, and a remote physical object would move in a corresponding manner.

The authors in [7] propose a system where users can collaborate remotely on a design project. The system introduces us to the idea of a Collaborative Virtual Design Environment (CVDE). These systems center on the use of a Computer Aided Design/Engineering environment to construct an object. Much like the systems described in [6], objects are manipulated by users in a distributed fashion, however, in this case, the objects are virtual objects under design.

The authors of [8] utilize the Occulus Rift to construct a virtual operating room. The authors propose using the virtual operating room as a training environment for medical professionals. The tools provided by this work allow users to gain familiarity with a space they need to work in, but which may have limited accessibility to the future workforce.

Another medical related use of the Occulus Rift is described in [9]. This work focuses on the potential use of virtual reality to provide new ways to explore existing data. In particular, the study focuses on how radiologists are able to examine 3-dimensional data reconstructed from a head CT scan. The system developed by the authors allows users to visualize the whole of the data rather than slices of the data that exist on 2-dimensional outputs. The hope the authors express is to be able to use this technique to increase a physician's knowledge of the relationship between the collected data and a diagnosis. This work is similar to the 3-dimensional reconstruction work in [5], but the data involved is much more complex.

SYSTEMS USED IN CURRENT RESEARCH

The more recent advances focus on Virtual Reality Systems and Augmented Reality systems, which are the two most common technologies used to create remote collaborative environments. These two types of systems are described in this section.

A. **Augmented Reality Systems**

Augmented reality systems allow users to visualize the world around them while providing information that enables users to complete a task more quickly or more efficiently. Generally there are two types of augmented reality systems, Projection Systems and Wearable Systems.

Projection systems consist of a projection device that is stationary, at least during use, and special glasses, frequently polarized, so that images may be seen in 3 dimensions. The projection equipment and glasses utilized are similar to systems used by the entertainment industry to produce 3dimensional video.

Wearable systems typically consist of a pair of eye glasses fitted with a self-contained projection screen. Typically these devices are connected to either a PC or a mobile device, which can perform computation and provides network access required by some applications. Readers interested in the techniques and challenges of constructing a wearable system may wish to consult [10].

B. **Virtual Reality Systems**

Virtual reality systems provide the user with a view of a virtual world. While typically virtual reality is associated with video games, virtual reality also has applications in training and education. High fidelity personal virtual reality systems provide opportunities for users to gain experience in vitalized environments that might not be possible, or frequent in the real world.

K-12 APPLICATIONS

In describing the reasons Computer Science should be incorporated into computer science, the authors of [11] state:

> The power of computers stems from their ability to represent our physical reality as a virtual world and their capacity to follow instructions with which to manipulate that world.

It seems only natural, given that setting, that Virtual and Augmented reality should play a part in learning in a K12 environment. [12] further explores this idea by providing suggestions for how K-12 educators might utilize Augmented Reality in the classroom, without exploring any technical details of how this is to be implemented.

In [13] explored the possibility of utilizing augmented reality to teach subjects where students truckle to visualize physical phenomenon, such as DNA's double helix. The system described used a tablet computer based Augmented Reality system to show 3-dimensional objects when an identification tag was read on a physical object, such as a book. In their results, the authors discus reactions of local K-12 teachers to this technology.

Applications of a tag based Augmented Reality system to Astronomy are discussed in [14]. As with the applications in [13], astronomical applications are hard for students to visualize, primarily due to the great distances involved. The system presented in [14] allows students to interact with markers representing astronomical bodies in order to solve problems, such as determining relative positions of the Earth, Sun, and Moon. A computer system is used to identify the markers and project representations of the astronomical bodies as students solve the problems. In analyzing the effectiveness of the application, the authors studied the approaches students took to solve problems, based on recordings of marker positions.

The authors of [15] present an augmented reality system that is intended to be utilized by teachers as a means of gaining a better perception of student learning and engagement. The targeted audience for this technology is classrooms where students are studying independently on a variety of subjects, where the teacher is expected to be able to aid many students in rapid succession. The paper discusses the design, deployment, testing and analysis of the system when utilized in real classrooms.

[16] describes an application intended to interest K-12 students in STEM fields. The application, PlayScope, utilizes a smartphone like device to augment the information presented to students through a microscope. The application allows students to play games where microorganisms displayed on the screen interact with a virtual game, such as a soccer field.

In a very short article, [17] discuss an augmented reality system that can be utilized in a school gymnasium. The system is designed such that markings on the floor can be changed using a projection system, rather than physically marking the floor with tape or paint. The system uses a series of projectors with attached cameras to project a mosaic on the floor. The cameras allow the content displayed on the floor to change based on movement students.

HIGHER EDUCATION APPLICATIONS

In [18], the authors present applications of a commercial projection based holographic system called zSpace [19]. The zSpace system consists of a tablet like workstation where holographic images are projected above the screen. Users wear a pair of polarized glasses to enable viewing the objects in 3 dimensions. Objects are manipulated using a special stylus. While the primary application presented in this paper a CVDE system, the authors also present the use of the zSpace system in a classroom like setting. In the classroom like setting, all participants wear the required glasses and a projector presents the holographic image of an object on a screen at the front of the room. Some subset of the participants are able to manipulate the projected objects utilizing the workstation devices.

In [20] the authors describe an experiment using Google Glass to help young researchers learn to be more confident and self-reliant in a wet-laboratory environment, and has application chemistry and biology laboratories.. The study provided users with the ability to see step by step procedures during a laboratory experiment. Additionally, users were able to document their laboratory experiments in real time using gestures that interacted with Google glass, enabling users to work more efficiently.

The authors of [21] present a HoloLens application where a professor is able to remotely guide a student performing field research. The field research illustrated in the paper is a geology expedition. The application allows the student to send video to the professor using a HoloLens. The professor is, presumably, in his office at the university. The professor can then augment the video in order to provide guidance to the student working in the field.

PROFESSIONAL TRAINING APPLICATIONS

The authors of [8] utilize the Occulus Rift to construct a virtual operating room. The authors propose using the virtual operating room as a training environment for medical professionals. The tools provided by this work allow users to gain familiarity with a space they need to work in, but which may have limited accessibility to the future workforce.

Another medical related use of the Occulus Rift is described in [9]. This work focuses on the potential use of virtual reality to provide new ways to explore existing data. In particular, the study focuses on how radiologists are able to examine 3-dimensional data reconstructed from a head CT scan. The system developed by the authors allows users to visualize the whole of the data rather than slices of the data that exist on 2-dimensional outputs. The hope the authors express is to be able to use this technique to increase a physician's knowledge of the relationship between the collected data and a diagnosis. This work is similar to the 3-dimensional reconstruction work in [5], but the data involved is much more complex.

Medical applications of wearable augmented reality systems are explored in [22] and [23]. Both of these papers use the HoloLens as an augmented reality platform.

[22] offers several potential applications, including teaching anatomy and augmenting mannequins used as a human stand in, along with several applications intended to guide novice physicians during their work, particularly during surgery. The authors also present two prototype applications. The first application is a surgery simulator that uses a mannequin as a stand-in for a human body, but overlays images of human tissues on that mannequin. The second application allows visualization of CT scans, much like [9].

[23] explores using an augmented reality system to understand the biomechanics of the human body. The system describes uses a Microsoft Kinect sensor to track the motion of the human body and displays information about the motion on either a Hololens or a mobile device. The goal of the system is to create a system that portrays human movement in a manner such that practitioners can gain a better understanding of how the body moves.

An application of virtual reality systems to dental surgical training is proposed in [24]. While this work is clearly a work in progress, the focus of the work is on teaching future dentists proper decision making techniques during surgery. To enhance this work, the development of a virtual dental operating room is proposed.

OTHER EDUCATIONAL USES

One application which does not quite fit the traditional educational environment is the use of augmented reality in museum displays. The authors of [25] explore the development of an augmented reality system to support an exhibit on the Egyptian *Tomb of Kitines* at the Royal Ontario Museum. The deployed system allows museum visitors to explore historic artifacts in a new way, by not only seeing the object, but being able to interact with a virtual replica of the object.

CONCLUSION

There are several common themes presented through the works referenced here. The articles all attempt to provide a better understanding of some process using either virtual or augmented reality. Several of the applications involve providing individualized guidance to students or practitioners working in fields such as medicine and biology. Other applications provide users with augmented representations of systems they are expected to learn and understand as a part of their education. The augmentation occurs as text, audio, or images, and may consist of information supplied in real time or as a pre-recorded data.

We are certain these applications just scratch the surface of what is possible given the relative youth of the technologies involved, especially when wearable devices are concerned.

REFERENCES

[1] Microsoft. Microsoft hololens - the leader in mixed reality technology. [Online]. Available: https://www.microsoft.com/en-us/hololens

[2] X. Glass. [Online]. Available: https://www.x.company/glass/

[3] Oculus. Oculus rift. [Online]. Available: https://www.oculus.com/rift/

[4] G. Rodenbery. Holodeck. [Online]. Available: http://www.startrek.com/database_article/holodeck

[5] B. Parvin, J. Taylor, and G. Cong, "Deepview: A collaborative framework for distributed microscopy," 12 1998. [Online]. Available: https://escholarship.org/uc/item/4t46b2qd

[6] S. Brave, H. Ishii, and A. Dahley, “Tangible interfaces for remote collaboration and communication,” in *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work*, ser. CSCW ’98. New York, NY, USA: ACM, 1998, pp. 169–178. [Online]. Available: http://doi.acm.org/10.1145/289444.289491

[7] I. Horvath, J. S. M. Vergeest, and Z. Rusak, “Six ingredients of collaborative virtual design environments,” in *DS 30: Proceedings of DESIGN 2002, the 7th International Design Conference*. Bristol,UK: The Design Society, 2002, pp. 67–74.

[8] J. A. Juanes, J. J. Gómez, P. D. Peguero, J. G. Lagándara, and P. Ruisoto, “Analysis of the oculus rift device as a technological resource in medical training through clinical practice,” in *Proceedings of the 3rd International Conference on Technological Ecosystems for Enhancing Multiculturality*, ser. TEEM ’15. New York, NY, USA: ACM, 2015, pp. 19–23. [Online]. Available: http://doi.acm.org/10.1145/ 2808580.2808584

[9] J. E. Venson, J. Berni, C. S. Maia, A. M. da Silva, M. d’Ornelas, and A. Maciel, “Medical imaging vr: Can immersive 3d aid in diagnosis?” in *Proceedings of the 22Nd ACM Conference on Virtual Reality Software and Technology*, ser. VRST ’16. New York, NY, USA: ACM, 2016, pp. 349–350. [Online]. Available: http://doi.acm.org/10.1145/2993369.2996333

[10] A. Maimone, A. Georgiou, and J. S. Kollin, “Holographic near-eye displays for virtual and augmented reality,” *ACM Trans. Graph.*, vol. 36, no. 4, pp. 85:1–85:16, Jul. 2017. [Online]. Available: http://doi.acm.org/10.1145/3072959.3073624

[11] K.-. C. S. F. S. Committee, “K-12 computer science framework,” New York, NY, USA, Tech. Rep., 2016.

[12] L. J. Leighton and H. Crompton, “Augmented reality in k-12 education,” 02 2017.

[13] A. M. Teichner, “Augmented education: Using augmented reality to enhance k-12 education,” in *Proceedings of the 2014 ACM Southeast Regional Conference*, ser. ACM SE ’14. New York, NY, USA: ACM, 2014, pp. 45:1–45:3. [Online]. Available: http:
//doi.acm.org/10.1145/2638404.2638519

[14] S. Fleck, M. Hachet, and J. M. C. Bastien, “Marker-based augmented reality: Instructional-design to improve children interactions with astronomical concepts,” in *Proceedings of the 14th International Conference on Interaction Design and Children*, ser. IDC ’15. New York, NY, USA: ACM, 2015, pp. 21–28. [Online]. Available: http://doi.acm.org/10.1145/2771839.2771842

[15] K. Holstein, G. Hong, M. Tegene, B. M. McLaren, and V. Aleven, “The classroom as a dashboard: Co-designing wearable cognitive augmentation for k-12 teachers,” in *Proceedings of the 8th International Conference on Learning Analytics and Knowledge*, ser. LAK ’18. New York, NY, USA: ACM, 2018, pp. 79–88. [Online]. Available: http://doi.acm.org/10.1145/3170358.3170377

[16] C. LaPlante, M. Nolin, and T. Saulnier, “Playscope: Augmented microscopy as a tool to increase stem engagement,” in *Proceedings of the 12th International Conference on the Foundations of Digital Games*, ser. FDG ’17. New York, NY, USA: ACM, 2017, pp. 63:1–63:4.
[Online]. Available: http://doi.acm.org/10.1145/3102071.3116223

[17] C. Xie, Y. Kameda, K. Suzuki, and I. Kitahara, “Large scale interactive ar display based on a projector-camera system,” in *Proceedings of the 2016 Symposium on Spatial User Interaction*, ser. SUI ’16. New York, NY, USA: ACM, 2016, pp. 179–179. [Online]. Available: http://doi.acm.org/10.1145/2983310.2989183

[18] A. K. Noor and R. Aras, “Potential of multimodal and multiuser interaction with virtual holography,” *Advances in Engineering Software*, vol. 81, p. 1âAS¸6, 2015. [Online]. Available: http://www.sciencedirect.˘ com/science/article/pii/S096599781400177X

[19] zSpace. zspace. [Online]. Available: http://zspace.com/

[20] G. Hu, L. Chen, J. Okerlund, and O. Shaer, “Exploring the use of google glass in wet laboratories,” in *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, ser. CHI EA ’15. New York, NY, USA: ACM, 2015, pp. 2103–2108. [Online]. Available: http://doi.acm.org/10.1145/2702613.2732794

[21] H. Chen, A. S. Lee, M. Swift, and J. C. Tang, “3d collaboration method over hololens™and skype™end points,” in *Proceedings of the 3rd International Workshop on Immersive Media Experiences*, ser. ImmersiveME ’15. New York, NY, USA: ACM, 2015, pp. 27–30. [Online]. Available: http://doi.acm.org/10.1145/2814347.2814350

[22] D. Gasques Rodrigues, A. Jain, S. R. Rick, L. Shangley, P. Suresh, and N. Weibel, “Exploring mixed reality in specialized surgical environments,” in *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, ser. CHI EA ’17. New York, NY, USA: ACM, 2017, pp. 2591–2598. [Online]. Available: http://doi.acm.org/10.1145/3027063.3053273

[23] A. Voinea, A. Moldoveanu, and F. Moldoveanu, “Bringing the augmented reality benefits to biomechanics study,” in *Proceedings of the 2016 Workshop on Multimodal Virtual and Augmented Reality*, ser. MVAR ’16. New York, NY, USA: ACM, 2016, pp. 9:1–9:6. [Online].
Available: http://doi.acm.org/10.1145/3001959.3001969

[24] N. Vannaprathip, "An intelligent tutoring system for situated decision making in dental surgery," in *23rd International Conference on Intelligent User Interfaces*, ser. IUI '18. New York, NY, USA: ACM, 2018, pp. 681–682. [Online]. Available: http://doi.acm.org/10.1145/ 3172944.3173154

[25] I. Pedersen, N. Gale, P. Mirza-Babaei, and S. Reid, "More than meets the eye: The benefits of augmented reality and holographic displays for digital cultural heritage," *J. Comput. Cult. Herit.*, vol. 10, no. 2, pp. 11:1–11:15, Mar. 2017. [Online]. Available: http://doi.acm.org/10.1145/3051480

Paul Bender is an Assistant Professor of Software Engineering at Ohio Dominican University in Columbus,OH. He previously taught Computer Science at McNeese State University in Lake Charles, LA. He holds a B.S. in Computer Science from Missouri State University, Springfield, MO, an M.S. in Computational Mathematics from Ohio University, Athens, OH, and a Ph.D. in Computer Science and Engineering from Wright State University, Dayton, OH. These degrees were completed in 1998, 2004, and 2008, respectively. Dr. Bender's research interests include various topics in Operating Systems and Networking, including adhoc networks, real time systems, multimedia communications, and system security. The focus of his current research is on the application of test driven and behavior driven development to distributed real time sensor/actuator networks. He is a member of the ACM, IEEE, IEEE Computer Society, and ASEE.

Integration of product data management systems in Augmented Reality maintenance applications for machine tools

Christian Kollatsch, Marco Schumann, Sven Winkler and Philipp Klimant
Division Process Informatics and Virtual Product Development, Professorship for Machine Tools and Forming Technology, Institute for Machine Tools and Production Processes, Chemnitz University of Technology, Reichenhainer Straße 70, 09126 Chemnitz, Germany
christian.kollatsch@mb.tu-chemnitz.de

Introduction

1.1. Augmented Reality for maintenance

The ongoing future project Industry 4.0 addresses new concepts for linking machine tools and mobile devices, information transparency as well as the field of technical assistance. It is a goal to collect data during the production process, to manage it in a proper way and afterwards to utilize it in a beneficial manner. In this environment, Augmented Reality (AR) is an arising technology that introduces a wide range of applications in the fields of assembly and maintenance [1]. AR enables it to add virtual content to the reality with the help of mobile devices as AR glasses, smartphones, tablet PCs etc. This technology can be used to add relevant information to a production environment or to show manual instructions with the help of 3D animations on the real machine.

For evaluating, processing and visualizing data, access to different data sources is required and causes a huge effort of implementation. In this paper, especially the use of product data management (PDM) systems for the usage for AR-based maintenance for machine tools is analyzed and implemented. Many product data that are already stored in these systems could be used for an AR maintenance application. Additionally, the PDM system could be used to create and combine new documentation data. However, the conjunction between the AR and the PDM side is a crucial problem for companies to use an AR maintenance application effectively in a productive environment.

1.2. Concrete problem and objective

One problem is that current PDM systems are not aware of AR applications and therefore they offer no native interfaces for them. This situation is handled by converter software in current approaches (see Figure 1), a manual process which is unidirectional and time consuming. Another problem is that a creation software is mostly required to prepare the AR content from the PDM system data.

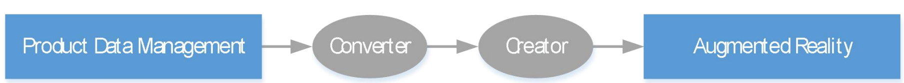


Figure 1. Current data flow between PDM and AR.

This paper explains a new approach that directly links PDM and AR software together. The advantages of such a solution are convincing: the newest data can be obtained from the PDM system without indirection and the AR application is able to write data back to the PDM system (see Figure 2). Furthermore, current PDM software is very flexible und modular, which makes it possible to create AR content with the help of the PDM system.

Figure 2. Target data flow between PDM and AR.

Hereafter, this paper gives a conclusion of current maintenance tasks and documentations in the field of machine tools. After this, the AR technology is described and present maintenance systems with AR support are discussed to give an overview of the state-of-art in the research field. Subsequent, the new approach is discussed including details about PDM interfaces and different integration concepts. The final discussion summarizes the advantages of the presented approach and shows why the direct connection of PDM and AR is worth the efforts.

2. State of the art

2.1. Maintenance tasks of machine tools

The maintenance of machine tools includes all activities for the preservation or the return in the operational state of the machine tool to fulfill its functionality [2]. It is an important part to maintain the production processes. If the wear of the machine tool is too high, there will be a failure after a certain time. One important part for the technician is the assessment of the current state of the machine. Besides the machines, the technicians and computer systems have an important role for the maintenance. For achieving an effective process, a foundation of digital data from the planning up to the maintenance task is required. Furthermore, expert knowledge of the technicians is necessary. However, computer systems can support them, make the process faster, and free of errors.

Activities of the technicians that are important in maintenance and that can be supported with Augmented Reality are manual operations and monitoring of the machine systems. Manual operations are the assembly and disassembly of components, control of the machine, cleaning, grinding and welding [2]. With a high complexity of the machine, the tasks for the technicians are also complex. The use of Augmented Reality applications can reduce the complexity by showing the single tasks gradually in the right place. These steps have to be planned during the design of the maintenance. In addition, dangerous situations for the humans can be visualized to reduce the risk of injuries for technicians.

Besides the help for manual operations, information of diagnosis and condition-monitoring systems can be helpful for technicians [2]. With diagnosis systems for components, single errors of the machine can be found. In contrast, condition-monitoring systems observe the state and context of the whole machine. With the provided data of these two systems and the instructions of the AR application, the technicians can find the causes for failures faster and make better decisions for the maintenance work.

2.2. Maintenance documentation of machine tools

During the planning of the maintenance, the documentation for the technician is created [2]. The content of the documentation is every single activity for the technician. This can be assembly instructions, texts, drawings, listings and marks on the machine. Today, the most documentations for maintenance are on paper. Sometimes there are also digital documents. However, there is no direct reference to the machine and no interaction with the technician.

The documentation on paper is time-consuming, sensitive to errors and inconvenient for the technician, because there is no direct correlation with the machine [2]. The information is not adapted to the user or the machine. Furthermore, external data sources like condition-monitoring systems cannot be integrated. These disadvantages can be corrected by using AR-based systems, which visualize the information user-friendly and superimposed over the machine [1]. A problem is that the existing documents for maintenance cannot be used directly but have to be processed. Today, many data of the machines is available in PDM systems. These data can be used for creating AR applications for maintenance. This process is described in the following sections.

2.3. Augmented Reality applications for machine tools

With Augmented Reality, production environments can be enhanced with virtual data to support the human work. Examples are the adding of virtual parts (3D) to a real machine for a design review or visualization of relevant information (2D) of the current machine state to the user. In [3] an AR application for the maintenance of a gearbox of a milling machine was developed. To show instructions for particular working steps, animated 3D models are superimposed over the gearbox. With a visualization on a tablet PC, the manual work of the human is supported. Another application is the user-friendly visualization of monitoring and process data of a machine. In [4] an AR application was developed that is connected to the CNC (computer numerical control) of the machine and visualizes all relevant information of the control unit on a transparent window on the machine. This representation of the data improves the comprehension of processes and simplifies operations.

To deploy AR applications for machine tools in an effective, simplified and quick way, AR software libraries and frameworks can be used. With this approach, the content is in the focus of the creating process of the AR application and not the complex AR technology. One example of an AR framework is DWARF (Distributed Wearable Augmented Reality Framework) [5]. With a software architecture that defines the AR components as services, they can be changed, combined and reused. One toolkit that supports the user to create an AR application is DART (The Designer's Augmented Reality Toolkit) [6]. It uses and extends an existing development environment to allow the user to combine all AR information with a graphical user interface (GUI). This accelerates the creation process of the application and reduces its complexity.

An AR creation system especially for assembly instructions is described in [7]. A special editor was created to arrange the separate assembly steps, 3D models and additional information. CAD models can be imported and converted for a quick workflow. The 3D models can be aligned in the editor by the usage of photos of the real environment. Also in [8] an editor for an assembly instruction system with AR is created. With a modular software architecture, various external systems can be integrated based on middleware. In [9] an Augmented Reality framework was designed to support the human and reduce complexity in a smart factory. The focus was the training of operators for new machines.

2.4. Connection between Augmented Reality applications and PDM systems

Besides the integration of live data, the quick integration of CAD data and information from PDM systems are important for the maintenance of machine tools with AR. In [12] a system concept is described consisting of four components: PLM system (product lifecycle management), scene generator, AR application and data repatriation. With the scene generator, all the needed data from the PDM system and the maintenance sequence definition is combined and saved in a maintenance file. This file contains all information for the AR application. The protocol of the maintenance is written back to the PDM system. The objective is a consistent and replicable workflow. Also in [13] a system architecture for assembly with AR is described. The objective is the automation of the content creation workflow from PDM and CAD to AR for workers on the production line. Therefore, a design for assembly (DFA) software tool is integrated to the design systems CAD and PDM. For the 3D models, the standard format file STEP (standard for the exchange of product model data) is used. The system was positive validated in two applications. In the project AVILUS [14], the capturing of data from the PLM process and integration in an AR system was researched. Therefore, a comprehensive information model was created. With this solution, data from different sources can be used for the maintenance with an AR application.

2.5. Own preliminary work with Augmented Reality

The AR framework ARViewer [10] is developed at the Chemnitz University of Technology particular for the field of machine tools. It allows the creation of new individual and complex AR scenarios for different machines without programming the AR technology for every use case. Therefore, several interfaces to tracking systems, camera interfaces and especially to external systems such as CNCs and MES systems (manufacturing execution systems) are available. With a modern 3D visualzation, user-friendly applications can be created for different mobile devices like tablet PCs and AR glasses.

Figure 3. (a) 3D visualization of condition monitoring and simulation values, energy and data flows, product and process information of the press [10]. (b) Augmented Reality press connected to the real NC control [10].

One created application with the AR framework ARViewer is the AR press [10], [11] (see Figure 3). For demonstration purposes of different press technologies, various press components, e.g. a motor and a hydraulic unit, were attach to a four-meter high rack. Additionally, a transfer was installed and controlled by a motion-control system. With the AR application on tablet PCs and monitors, the whole press and its functionality is visualized in 3D. Therefore, the AR application is connected to the motion-control system to receive and send control values. With these values, the 3D model is moved and simulation values are synchronized. The AR application allows the user to look inside the press, get monitoring information, control the stroke and get simulation, energy flow and data flow information in a descriptive way.

2.6. Structure of Augmented Reality applications

Augmented Reality (AR) is the enhancement of the real environment with virtual data. Therefore, several software components are required [14]. An important characteristic is the adjustment of the virtual information to the view of the user. Therefore, a tracking component is required to calculate the position, orientation and size of the virtual model. To capture the real environment for an optical tracking, a camera component is needed. To show the virtual models and additional information to the user in real time, a visualization component is required. For complex AR applications for machine tools, additionally a data management component has to be implemented. Another important part of AR applications is the possibility for user interactions. With the entirety of these components, the AR scene is composed (see Figure 4).

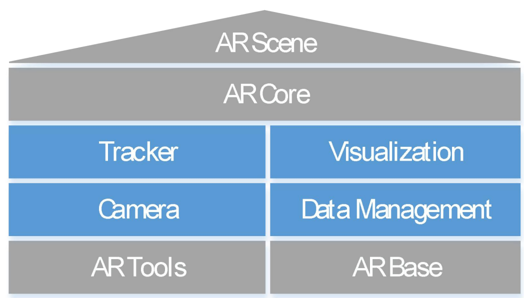


Figure 4. Structure of the Augmented Reality framework ARViewer [10].

In this paper, the main focus is the data management component. In an AR application, 3D models and additional information can be used [14]. These data can be imported and arranged at compile time of the application or accessed over interfaces to external systems at runtime of the application, e.g. from PDM systems. For the use of 3D models, CAD data is the foundation in the field of machine tools. In many cases, the CAD data have to be simplified and preprocessed to use them in a real-time application. The processing of the data can be executed in the CAD software or a special software tool depending on the complexity of the model and possibilities of the software. With the different software systems, there are different data formats available that have to be converted.

2.7. Summary of the state of the art

Maintenance is an important part of the life cycle of a machine tool and influences the productivity of a production environment. Therefore, it is a research focus to optimize maintenance tasks to save costs, reduce failures and to increase productivity. Section 2 described the essentials of maintenance tasks and maintenance documentation. Next, the usage and possibilities of Augmented Reality in the field of machine tools were shown. While the maintenance scenario is always well described and the benefits of the AR usage are examined, most concepts omit the part of the data management. The analyzed concepts use additional software tools and need much extra and often manual work to create new Augmented Reality maintenance scenarios. Thereby, automated workflows can improve the productivity and quality essentially.

Therefore, it is the objective of this paper to introduce a concept to connect PDM systems with all the needed data to the AR maintenance application directly (see Figure 2). This means that no additional converter or creation software is required between the PDM system and AR application. All the data processing should be done in the source systems of the data or the PDM system. These data can directly be loaded over network into the AR application. With this concept, the effort for creating new AR maintenance scenarios should be decreased strongly which reduces the burden to use AR technologies in an industrial environment.

3. Integration of a product data management system

3.1. Overall concept for the Augmented Reality creation process

The new method consists of the usage of the PDM system to generate the complete AR maintenance application. No extra software tool should be used to create a new maintenance use case (compare Figure 1 and Figure 2). All the required data is collected and created in the PDM system. On the other side, there is one AR application that is created and configured to read the created maintenance data. Therefore, essentials of the required data and PDM system interfaces are described in the next sections. The main focus in this paper is the integration concept for the PDM system into the AR application.

3.2. Required data for maintenance tasks

For the maintenance of machine tools with an AR application various data is required. For AR applications, 3D models are needed to show the information in the right place and visualize 3D components. Furthermore, maintenance information for the machine is required that are usually available as a handbook from the manufacturer. Most handbooks consist of textual descriptions and pictures. Additionally, there are hints for danger situations and environment protection. All the information has to be prepared in the PDM system for a later use in the AR application.

A huge problem for working with data in different software systems are the different provided data formats. The basis of AR 3D models can be CAD models of the machine. In many cases, they cannot be used in the original format and have to be converted and simplified because of their size and complexity. An existing standard exchange format is STEP (exchange product model data, ISO 10303 [15]) that can be processed in many software systems. In the example of this paper, the file formats OBJ [16] and MTL [16] are used because of the existing interfaces of the AR software.

3.3. Interfaces to product data management systems

In a company, much information is processed and many data types have to be handled. Examples are CAD data, presentations and pictures. These data have to be saved in a structured way, so that every employee can find and use them. For this task, a product data management (PDM) system can be used. Important functions are the version control of all documents for the tracing of revisions and the locking of documents while they are changed by a user.

PDM software consists of a client-server architecture. Thereby, the data is managed centrally on a server and the user can read and write data from different clients. The used PDM software defines three layers: presentation layer, application layer and data layer. The presentation layer is the communication interface between the user and the software. With graphical user interfaces (GUI), the user can work with the data in a convenient way. The application layer provides functions to manage all the different data. The data layer is responsible for storing the data.

For the realization of the concepts in this paper, the PLM system Siemens Teamcenter [17] is used. To connect other applications to this PLM system, a PLMXML [18] interface is provided. Thereby, the data is stored in the XML format and can be exchanged with the AR application. The different ways to use this interface and other functionalities of the PDM system are described in the next section.

3.4. Integration concepts for Augmented Reality applications

For the usage of a PDM system with an AR application for maintenance tasks of machine tools, the following three different integration concepts are created and evaluated.

Concept 1: Data exchange with the PLMXML interface

For concept 1, the PLMXML interface of the PDM system is used. The maintenance planner arranges all the needed data for a maintenance task in the PDM system and exports them over the PLMXML interface in a folder of the file system (see Figure 5). This dataset can be loaded from the AR maintenance application and the maintenance task can start. At the end of the work, changed and created data of the AR application, e.g. a maintenance protocol, is written back to the dataset in the file system and can be imported over the PLMXML interface to the PDM system.

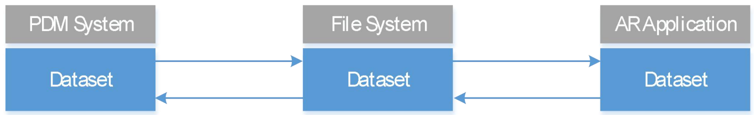


Figure 5. Concept 1: Data exchange with the PLMXML interface.

The advantage of this concept is that the AR application can be used offline with the local dataset of the maintenance task and no permanent connection to the PDM system is required. Furthermore, the data in the PDM system is not locked and can be used and changed by other users. Disadvantages are that the external datasets have to be managed manually and there is no warranty that the local dataset corresponds to the latest version.

Concept 2: Data exchange with check-out

For concept 2, the check-out process of the PDM system is used. Therefore, a new file format for the AR data is defined and linked with the AR maintenance data in the PDM system and the AR application. With the help of the graphical user interface (GUI) of the PDM system and the new linked file format, the user can start the AR application with the selected maintenance task (see Figure 6). Changed and created data from the AR application can directly be written back to the PDM system.

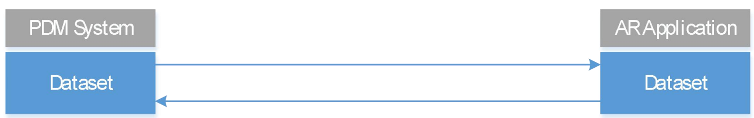


Figure 6. Concept 2: Data exchange with check out.

The advantage of this concept is that no data exchange over the file system is required. Furthermore, always the newest maintenance data from the PDM system is used. The disadvantages are that the mobile device with the AR application must have an online connection to the PDM system and the used data in the PDM system is locked for other users.

Concept 3: Data exchange with a web server

For concept 3, a web server is used between the PDM system and the AR application. Like in concept 1, the maintenance data from the PDM system is exported over the PLMXML interface to an external folder. In contrast to concept 1, the maintenance dataset is stored on a web server (see Figure 7). In this way, many maintenance AR applications can connect to the web server to get the provided data for the current use case. In addition, changes of the maintenance data can be updated in the PLM system over the web server.

Figure 7. Concept 3: Data exchange with a web server.

With this concept, the maintenance data is not locked in the PDM system, which can be important in different situation, e.g. the data has to be updated. Nevertheless, the maintenance data can be managed on a server and the AR application can get the newest maintenance data over an online connection.

4. Evaluation and discussion

4.1. Evaluation of the Augmented Reality maintenance process

The described concepts of the integration of a PDM system in an AR application were evaluated with the maintenance of a hydraulic aggregate of a machine tool (see Figure 8). For the hydraulic aggregate, a manual document with the detailed working steps for the maintenance and a complete CAD model exists. The following tasks were performed as examples for maintenance tasks:

1. Check of the oil level with the level indicator
2. Check of the tightness of junctions and pipes
3. Refill oil in a filter

The defined AR instructions can be visualized with a 3D overlay and additional information in the following way:

1. The oil container is highlighted with minimum and maximum labels
2. All important components and hard accessible areas for the check are highlighted
3. The refill point is highlighted and information for the usage of the filter is visualized

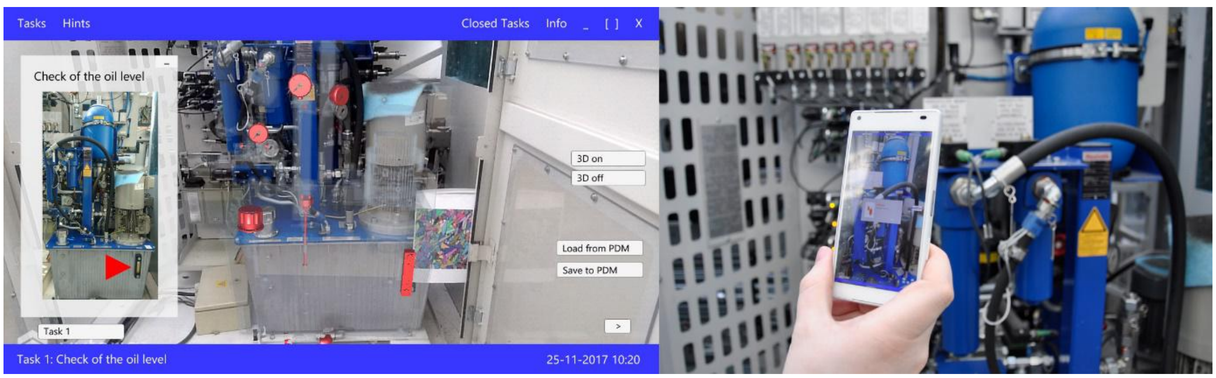


Figure 8. (a) PDM system connected AR visualization of a maintenance task with a description and a red highlight of the relevant machine component. (b) PDM system based AR visualization of a status message of the hydraulic aggregate on a mobile phone.

For the implementation of the AR maintenance application, concept 3 – data exchange with a web server – was chosen as the final solution because of its described properties. For the defined maintenance task, a new dataset was created in the PDM system. It consists of 3D models of the relevant machine parts, pictures, descriptions in text format and a text protocol.

The created dataset was exported over the PLMXML interface to the web server. The web server manages the data access from the AR maintenance application to the PDM data. With the help of the web server, the external maintenance dataset and the PDM data can be updated. In this way, the created maintenance protocol of the AR application can be saved in the PDM system.

The AR maintenance application is running on smartphones and tablet PCs. The use of a head-mounted display (HMD) is discussed in the next section. To detect the machine, a marker based tracking is used. The marker is attached at the bottom of the machine where it does not disturb any other process. After the start of the AR application, a connection to the web server is establish and the maintenance dataset is received based on the detected marker. Now, the user can selected the maintenance task to work on. With this selection, the help for the user is visualized by superimposing the real machine with virtual 3D components of the machine to work on together with pictures and text instructions (see Figure 8). With this method, the user is guided through the maintenance tasks. At the end of the work, the user can write a digital protocol, which is written back over the web server to the PDM system.

The described concepts show an effective workflow from creating and storing data in CAD and PDM systems through to an AR maintenance application to visualize these data to help the user with the maintenance tasks. With this method, the newest data can be used automatically in the AR application without changing its programming or other manual modifications. With the use of the PLMXML interface and the web server, many AR applications can be used simultaneously by different workers.

The objective of the presented concept was to reduce the time and the complexity of the creation process of an Augmented Reality maintenance application. The complexity is reduced by the usage of only one known system (PDM) for the user and the automation of several steps. With this concept, it is possible that the documentation planner can assume the task of creating AR maintenance scenarios. With the less and simpler tasks the creation time can also be reduced strongly.

4.2. Capabilities for automation of the process

The objective of the concepts in this paper is to enable a company to use an AR application for the maintenance of machine tools effectively. Therefore, the process to get the final AR data should be automatized as much as possible. The first step is to create a connection between the PDM system and the AR application. With this connection, the latest data for the maintenance tasks can be used and automatically be updated on changes without changing the AR application itself.

A further step is the usage of the CAD system to create information for the AR application. In the CAD model, important parts can be marked and additional text information can be attached to visualize them later in the AR maintenance situation. Furthermore, in the PDM system additional information can be created and linked to the 3D model to visualize them later. The PDM system has also functions to convert the 3D models in required AR data formats. Finally, the maintenance information can also automatically be derived from the existing machine documentation. These single steps are tested in the described AR maintenance application and accelerate the workflow for the AR maintenance process.

4.3. Capabilities for user interaction

The created AR application was evaluated with a smartphone and a tablet PC. The advantage of these mobile devices is the touchscreen where much detailed information can be visualized and the user can directly interact with it. For example, the user can write a short protocol for the result or errors of the maintenance with the on-screen keyboard. In addition, the selection of different use cases and options of the AR application is possible in an easy and well-known way.

Another possibility to use the AR application is a head-mounted display (HMD). The advantage is that the user has its hands free and can work on the machine simultaneously. In addition, all the information is visualized directly in the field of view of the user. Disadvantages are the limited field of view that can interfere the work and the limited amount of information that can be visualized. Additionally, the restricted possibilities of interaction can be a problem when much user input is required. A detailed evaluating the using of augmented reality devices in manufacturing was made in [19].

4.4. Conjunction with condition monitoring

In this paper, the connection between a PDM system and an AR application and a workflow for the AR data creation for the maintenance of machine tools is developed. Besides the documentation data, live data from the machine can be helpful for diagnosis and condition monitoring. In previous projects, an AR application for condition monitoring was developed by the Chemnitz University of Technology [10]. This application is directly connected to the NC control of the machine tool and can provide live information from the machine control and connected sensors. Furthermore, a 3D model is moved based on the NC data. Thereby, the process inside the machine can be visualized that is normally not visible (see Figure 9). Both applications shall be combined in the future to improve the described AR maintenance method.

Figure 9. AR application for condition monitoring of machine tools with a synchronous virtual 3D model [10].

5. Conclusion and Outlook

With the concepts of this paper, the system boundaries between PDM systems and AR applications for the maintenance of machine tools were reduced. Three integration concepts were introduced to enable an automated workflow between them. Every one of it has its own strengths and weaknesses, but in general, they all can make the creation process faster. This is an important aspect to use AR applications in a company. Usually, AR applications are planned and implemented as stand-alone software using local data or with proprietary interfaces for one special purpose. The connection to a PDM system allows creating an AR application for a wide range of tasks. Thus, the efforts for offering AR support for a single task decreases essentially. Additionally, all AR relevant content is managed by the PDM system and is therefore part of the software environment of the company. With the full integration of AR maintenance into the company's data structure, the usage of AR applications in an industrial environment is much easier, cheaper and could be more accepted. To test and verify the three concepts, a prototypical implementation for maintenance purpose was realized and presented in this paper. The first results of this are promising to prove the announced claims but further evaluations are necessary to get statements about the influence and the concrete benefits of an automated workflow with integrated AR.

References

[1] Palmarini R, Erkoyuncu J A, Roy R, Torabmostaedi H (2018) A systematic review of augmented reality applications in maintenance, Robotics and Computer-Integrated Manufacturing, Vol. 49, pp. 215-228

[2] Zhang A F, Cui L R, Zhang P (2013) Research on the Maintenance Strategy of CNC Machine Tool. In Proceedings of 20th International Conference on Industrial Engineering and Engineering Management, Springer, Berlin, Heidelberg, pp. 583-589

[3] Wang T, Liu Y, Wang Y (2008) Infrared marker based augmented reality system for equipment maintenance. Proceedings – International Conference on Computer Science and Software Engineering, CSSE 2008, Vol. 5, pp. 816-819

[4] Olwal A, Gustafsson J, Lindfors C (2008) Spatial augmented reality on industrial CNC-machines. Proceedings of SPIE, Vol. 6804, pp. 680409-680409

[5] Bauer M, Bruegge B, Klinker G, MacWilliams A, Reicher T, Riss S, Wagner M (2001) Design of a component-based augmented reality framework. Proceedings IEEE and ACM International Symposium, pp. 45-54

[6] MacIntyre B, Gandy M, Dow S, Bolter J D (2004) DART: A toolkit for rapid design exploration of augmented reality experiences. UIST: Proceedings of the Annual ACM Symposium on User Interface Softaware and Technology, pp. 197-206

[7] Wang J, Zeng C, Liu Y, Li S (2013) Integrated Content Authoring for Augmented Reality Based Product Manual Assembly Process Instruction. 43rd International Conference on Computers and Industrial Engineering, pp. 16-18

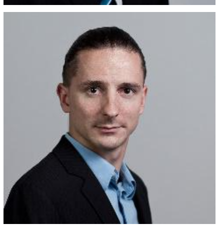
[8] Reinhart G, Patron C (2003) Integrating augmented reality in the assembly domain – fundamentals, benefits and applications. CIRP Annals-Manufacturing Technology, Vol. 52, no. 1, pp. 5-8

[9] Longo F, Nicoletti L, Padovano A (2017) Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context, Computers & Industrial Engineering, Vol. 113, pp. 144-159

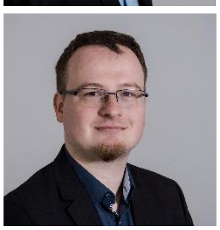
[10] Klimant P, Kollatsch C, Schumann M (2017) Augmented Reality Solutions in Mechanical Engineering. Proceedings of the ASME 2017 12th International Manufacturing Science and Engineering Conference, MSEC 2017, June 4-8, Los Angeles, CA, USA

[11] Kollatsch C, Schumann M, Klimant P, Lorenz M (2017) Industrial Augmented Reality: Transferring a Numerical Control Connected Augmented Realty System from Marketing to Maintenance. IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct), Nantes, pp. 39-41
[12] Stelzer R, Steger W, Saske B (2007) Effiziente Wartung komplexer Systeme mittels Augmented Reality – Neue Anwendungen der Informatik im Engineeringprozess. Gausemeier J and Grafe M: Augmented and Virtual Reality, 6. Paderborner Workshop, Paderborn.
[13] Sääski J, Salonen T, Hakkarainen M, Siltanen S, Woodward C, Lempiäinen J (2008) Integration of design and assembly using augmented reality. International Precision Assembly Seminar, Springer, Boston, MA, pp. 395-404
[14] Furht B (2011) Handbook of augmented reality. Springer Science & Business Media.
[15] https://www.iso.org/home.html, 27.11.2017
[16] http://www.cs.utah.edu/~boulos/cs3505/obj_spec.pdf, 27.11.2017
[17] https://www.plm.automation.siemens.com/en/products/teamcenter, 27.11.2017
[18] https://www.plm.automation.siemens.com/en/products/open/plmxml, 27.11.2017
[19] Elia V, Gnoni M G, Lanzilotto A (2016) Evaluating the application of augmented reality devices in manufacturing from a process point of view: An AHP based model, Expert Systems with Applications, Vol. 63, pp. 187-197

Christian Kollatsch received his Dipl.-Inf. (FH) and Master of Science degrees in Computer Sciences from the Westsächsische Hochschule Zwickau in 2008 and 2010. He is currently research associate at the Division Process Informatics and Virtual Product Development, Professorship for Machine Tools and Forming Technology at the Chemnitz University of Technology. His research topics include Augmented and Virtual Reality in mechanical and production engineering.



Marco Schumann received his Dipl.-Inf. (FH) in 2007 and his Master of Science (with award) in Computer Sciences in 2009, both from the Westsächsische Hochschule Zwickau - University of Applied Sciences Zwickau. Since 2009, he has worked as research associate at the Professorship for Machine Tools and Forming Technology at the Chemnitz University of Technology. His research topics include VR/AR technologies in the fields of production engineering and real-time collision prevention for machine tools as his graduation focus.



Sven Winkler received his B.Sc. in Print and Mediatechnology in 2014 and his M.Sc. in Microtechnology/ Mechatronics from the Chemnitz University of Technology in 2017. He is research associate at the Division Process Informatics and Virtual Product Development, Professorship for Machine Tools and Forming Technology at the Chemnitz University of Technology. His research interests are focused on the field of Digital Twin and Augmented Reality in connection with product data management systems.

Philipp Klimant holds a diploma in Electrical Engineering from the University of Applied Sciences Mittweida. He joined the Chemnitz University of Technology in 2007. His research focus is the development of machine simulation software, hardware in the loop simulation, use of augmented and virtual reality for Production and Medical Engineering. In 2013 he received his PhD in mechanical engineering. Since 2011 he is the head of the division Process Informatics and Virtual Product Development. He is responsible for the Virtual Reality Center Production Engineering (VRCP) laboratory. In 2016 he became also head of the Research Group Digital Production Systems and Virtual Reality of the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz.

SPECIAL ISSUE ON Internet-of-Vehicles Technologies

Guest Editors: Kan Zheng

Beijing University of Posts & Telecommunications, China

zkan@bupt.edu.cn

Internet of Vehicles (IoV) is the is an emerging system, which connects people, automotive, and other relative entries on the road. It plays an important role in dealing with safety or non-safety problems by advanced information and communications technology. IoV is expected to be one of essential parts of the fifth generation (5G) mobile networks. This special issue of E-Letter focuses on the promising current progresses on IoV technologies.

In the first article titled, "The Endowment of Vehicular Communications in Expediting 5G Technologies", *Ribal Atallah and Chadi Assi* from Concordia University, presented the plethora of research efforts seeking to kick-off the adopting and supporting 5G technologies in a vehicular environment. Vehicular Connectivity Challenges and Applications are firstly discussed. Then, Artificial Intelligence in Vehicular Environments are also investigated. It is expected to involve the vehicle manufacturers as well as industrial partners to the joint research in order to expedite the investigation of vehicular networking in helping to realize the IoT in 5G.

In the second article, "Cognitive Vehicular Ad Hoc Networks", by *Yuanwen Tian, Jun Yang, Jiayi Lu, Chao Han, and Zeru Wei* from Huazhong University of Science and Technology, gives the framework of cognitive vehicular ad hoc networks consisting of five layers, which are discussed in details as well. Then, a typical cognitive application scenario in healthcare field is presented. Enabled by cognitive computing, the framework of cognitive vehicular ad hoc networks might tackle the a few challenges.

Finally, the third article, titled "Towards Interest Broadcast Mitigation in Named Data Vehicular Networking", by *Z Syed Hassan Ahmed* from University of Central Florida, introduces Named Data Networking for vehicular communications followed by a bird's eye view on trending issues specifically the Interest Forwarding and Broadcast Storm due to the epidemic Interest flow. Furthermore, the recent efforts of Interest Broadcast Mitigation are summarized.

These articles provide different viewpoints for IoV techniques. It is believed that IoV will help to improve the qualities of our daily life in the near future. I am very grateful to all the authors for making great contribution and the E-Letter Board for giving this opportunity to this special issue.

KAN ZHENG [SM'09] (zkan@bupt.edu.cn) is currently a professor in Beijing University of Posts &Telecommunications (BUPT), China. He received the B.S., M.S. and Ph.D degree from, China, in 1996, 2000 and 2005, respectively. He is author of more than 200 journal articles and conference papers in the field of resource optimization in wireless networks, IoT, IoV networks and so on. He holds editorial board positions for several journals and also served in the Organizing/TPC Committees for more than 20 conferences such as IEEE PIMRC, IEEE VTC and so on.

The Endowment of Vehicular Communications in Expediting 5G Technologies

Ribal Atallah and Chadi Assi
Concordia Institute of Information and Systems Engineering, Concordia University
r.atalah@gmail.com, assi@ciise.concordia.ca

. Introduction

To cruise towards the 5G technology, intelligence, communication capabilities and processing power will need to be diffused across networks and mobile devices, empowering even the smallest of connected devices to do heavy computational tasks and run rich content and services. Soon enough, the Internet of Things (IoT) paradigm, which is a key enabling technology for the next generation 5G network, will become an absolute reality in modern wireless communications. At this point, an enormous number of "things" is being (and will continue to be) connected to the Internet at an unprecedented rate realizing the concept of IoT. Unquestionably, the IoT will remarkably impact people's everyday life. The Internet of Vehicles (IoV) emerges as a result of the fusion between the mobile Internet and the IoT. IoV technology refers to highly dynamic mobile communication systems that enable communication among vehicles and between vehicles and other wireless units (possibly mobile or stationary) using either V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure) or V2S (vehicle-to-sensor) or a combination of these several types of interactions. IoV enables information exchange between vehicles and their surroundings (*e.g.*, other vehicles, roadside units, portable devices carried by proximity users, etc.). Moreover, IoV features the processing, computing, sharing and secure release of information onto intelligent platforms, allowing these platforms to effectively guide and supervise the vehicles' behavior, and provision them with a variety of multimedia and mobile services. IoV leverages road objects (*e.g.,* traffic lights, cameras, speed sensors, etc.) with the ability to sense, process and exchange information related to the safety and comfort of passengers. It is envisioned to catalyze the feasibility of vehicle dynamics monitoring, intelligent navigation, fleet management, and value-added services become endless. For this purpose, the transportation research community is working collaboratively to build an end-to-end full-fledge Intelligent Transportation System (ITS) that enhances the user experience, reduces operational costs, and promotes a safe driving environment. A revolutionary transportation experience in the IoV era realizes several benefits, including, but not limited to: *a)* greater efficiency achieved through the reduction of fuel consumption through fuel-saving assistance that accounts for the driving distance, road conditions and driving patterns, *b)* increased safety using remote vehicle diagnostics that promote the responsiveness of service centers to driver drowsiness, vehicle theft, accidents as well as maintenance requests, *c)* higher reliability resulting from the reduction of vehicle downtime as well as expensive unplanned repairs following the use of vehicle performance tracking systems that send maintenance notifications, and *d)* enhanced quality of experience achieved through the support of infotainment services and on-the-fly access to information systems for the purpose of recuperating some knowledge (*e.g.*, about weather and roads conditions) or identifying hot spots (*e.g.*, rest stops, restaurants, parking spots, etc.).

The notable research enthusiasm to establish a revolutionary and efficient vehicular network is primarily due to the applications and services as well as their potential benefits and associated challenges. In fact, the major challenges restraining the fast and proper inauguration of an ITS are numerous, including: *a)* vehicles' high mobility, *b)* highly dynamic nature of the vehicular network, *c)* real-time nature of applications and *d)* a multitude of system and application-related requirements. Such challenges and opportunities serve as the background of the widespread interest in vehicular networking by governmental, industrial, and academic bodies. The inception of an operational vehicular network that lives up to today's expectations influenced the research industry to devote additional forces in testing, analyzing, and optimizing the various services offered by an ITS. Official reports as well as highly reputable magazines (*e.g.* [1]) are highlighting the significant role of vehicles in extending the IoT. In fact, vehicles will be a *major element* of the expanding IoT, with one in five vehicles having wireless communication capabilities by 2020, accounting for more than a quarter of a billion of the cars navigating along global roads. This is especially true since, according to Gartner Inc. (a leading information technology research and advisory company), the connected vehicle is already a reality, and in-vehicle wireless connectivity is rapidly spreading from luxury models and premium brands to high-volume mid-market models. Consequently, "*smart transportation is not our future, it is our present*" [2]. The journey of establishing an operational intelligent transportation system has begun, and it shall continue until a competent, efficient, and IoT-supportive vehicular network becomes a plain reality. This short paper sheds the light on some of the hot research topics, which accelerates the penetration of 5G technologies, particularly in a vehicular environment.

2. Vehicular Connectivity Challenges and Applications

2-A: Conventional Vehicular Network Connectivity

The transportation research industry has long anticipated the deployment of a full-fledged vehicular network that will help prevent accidents, facilitate eco-friendly driving, provide accurate real-time traffic information, and offer entertainment and leisure services to commuting passengers. The IoV offers a promising passage to achieve this goal. In fact, the ability of vehicles to behave as mobile sensors and/or data relays qualify them to be indispensable in the process of inaugurating an ITS. However, in a typical vehicular environment, a vehicle residing within the range of a RSU may directly communicate with that RSU using V2I communications and, hence, exploit a variety of services that happen to be offered by that RSU. However, upon its departure from the RSU's coverage range, the vehicle enters a dark area and loses all means of communication with the RSU. As illustrated in Figure 1, under several circumstances, vehicles residing in dark areas of a roadway require to communicate with an RSU. In this particular scenario, it is important to investigate the necessary conditions for establishing a connectivity path between an isolated vehicle and a distant RSU. Considering the highly dynamic topology of the underlying vehicular network, how many RSUs should be deployed along a roadway to enhance the network's connectivity? What is the tolerable and feasible end-to-end packet delivery delay under congested as well as free-flow traffic conditions? What are the necessary measures required to guarantee a threshold throughput level? Answers to these questions continue to push and promote several research studies.

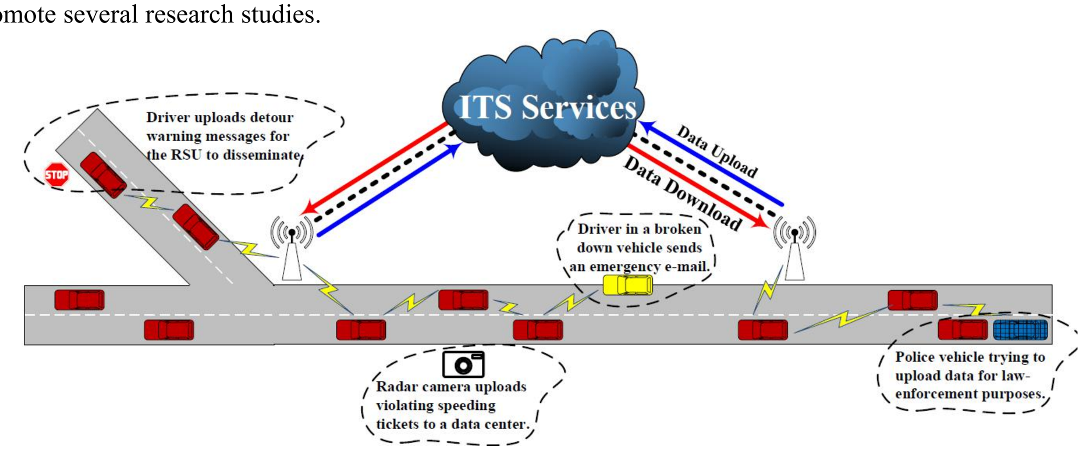


Figure 1: Connecting Vehicles in Dark Areas

2-B: Unmanned Aerial Vehicles as Store-Carry-Forward Nodes

Very recently, Unmanned Aerial Vehicles (UAVs), commonly known as drones, have posed themselves as a technology that can be harnessed for military, public as well as civil applications. The U.S. military has been exploiting UAVs for more than 25 years for border surveillance, reconnaissance, and striking purposes. UAVs provide timely disaster warnings and assist in speeding up rescue and recovery operations when the public communication network gets crippled. The overall drone production market is expected to top \$ 2.3 billion in value by 2027 [3], and as such, their use cases in a vehicular environment should be further investigated. The exploitation of UAVs privileged with store-carry-forward (SCF) capabilities in order to assist ground vehicles in the process of data delivery to a remote infrastructure RSU is expected to: a) increase the robustness of an available multi-hop path and b) mitigate the impact of uncooperative vehicles on the overall network connectivity. The characteristics of these UAVs such as their speed, number, capacity, as well as their communication capabilities should be determined after careful assessment of this application.

3. Artificial Intelligence in Vehicular Environments

3-A: Intelligent Energy-Aware Vehicular Network

The IoV is foreseen to support a full-fledged, smart, and efficient ITS by providing real-time traffic information, context-aware advertising as well as drive-through Internet access, provisioned through the help of RSUs acting as stationary IoT GateWays (IoT-GW) deployed along roadways. Several studies have presented supporting evidence about the fact that the significant barrier to the widespread deployment of RSUs is the cost of provisioning electrical grid power connections [4] as well as their remarkable energy consumption. Following the emerging need for energy-efficient wireless communications as well as the fact that grid-power connection is sometimes unavailable for RSUs, [5], it becomes clear and more desirable to deploy green energy-efficient RSUs, which are equipped with large batteries rechargeable through renewable energy sources such as solar and wind power [6] and [7]. Energy-efficient and QoS-oriented scheduling policies must be employed at the RSU in order to guarantee a desired level of performance in an eco-friendly environment, similar to the one illustrated in Figure 2. The major entangled challenge associated with the proper inauguration of a full-fledged connected vehicular network is the efficient control and management of the operation of multiple RSUs deployed in tandem along roadways. Indeed, the highly dynamic and stochastic nature of vehicular networks, the randomness in the vehicle arrival process as well as the diversity of the requested services give rise to a particularly challenging scheduling problem for the efficient operation of the IoT-GWs. Hence there exists a strategic need to establish a universal, green, intelligent and scalable scheduling policy which acclimates to the random characteristics of a vehicular environment and establishes a vigilant backbone ITS that supports the development of the IoV. Recent advances in training deep neural networks allows the exploitation of deep reinforcement learning techniques in order to train the backend ITS server to control the underlying vehicular networking environment in the most efficient way possible.

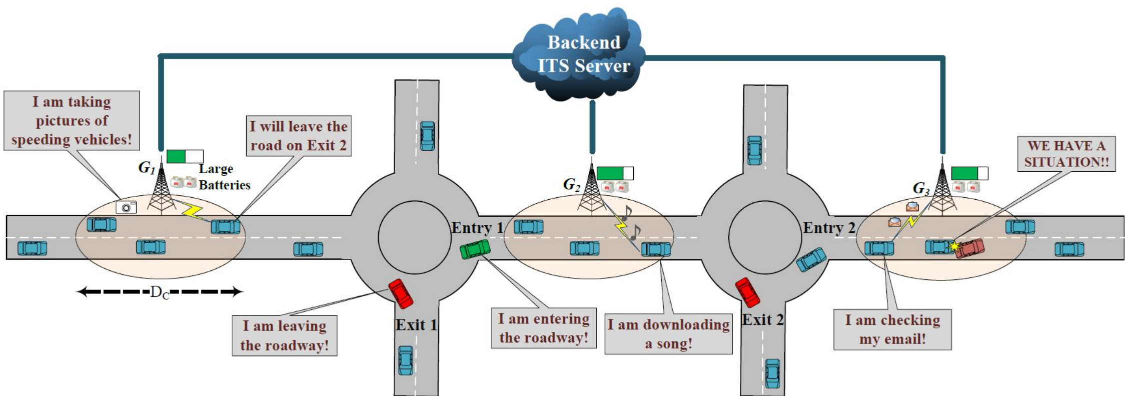


Figure 2: Energy-Limited Mult-RSU Vehicular Network

3-B: Controlling a RSU with Vehicular Edge Computing Capabilities

IoV features the processing, computing, sharing and secure release of information onto information platforms. Based on data from several sources, the IoV can effectively guide and supervise vehicles, and provide abundant multimedia and mobile Internet application services. Most of these services and applications may require significant computation resources and constrained time delays [8]. Hence, vehicular nodes are brought to deal with intensive computation tasks such as pattern recognition algorithms and video sequences preprocessing [9]. These kinds of tasks typically require complex calculations and pattern recognition algorithms, which are known to be exhaustive computation tasks and therefore require dedicated and powerful processors. The limited computational capability and low capacity resource of the vehicles' mounted modules present a major challenge to real-time data processing, networking and decision-making. As such, it becomes prevalent that the computation and resource-hungry applications pose a significant challenge to the resource-limited vehicular network. To cope with the explosive computation demands of vehicular nodes, cloud-based vehicular networking was promoted as a very promising concept to improve the safety, comfort as well as experience of the passengers. By integrating communication and computing technologies, cloud-enabled RSUs allow vehicles to offload their tasks that require high computational capabilities to the remote computation cloud, thus undermining the shortcomings of limited processing power and memory capacities of a vehicle's OnBoard Unit (OBU). Vehicular Edge Computing (VEC) is proposed as a promising motion that pushes the cloud services to the edge of the radio access network (RAN), namely the RSU, and provides cloud-based computation offloading within the RSU's communication range. The centralized nature of VEC poses significant challenges especially in a very highly dynamic environment such as a vehicular network. In fact, given the limited residence times vehicles spend within the radio coverage range of a RSU, that latter is bound to efficiently manage its VEC resources among offloaded tasks. Therefore, it has now become clear that a proper scheduling of the processing of the offloaded tasks is necessary to accommodate delay-intolerant tasks related to law enforcement and the safety of the transportation environment as well as delay-tolerant, yet computational exhaustive tasks such as video surveillance and various multimedia applications. Thus, the deployment of smart agents is a promising solution to control the operation of an RSU with VEC capabilities by utilizing machine learning techniques that allows the RSU to interact with the environment, learn the impact of its actions on the system, and eventually, optimize the overall network operation.

4. Conclusion

The future of the data communication landscape will be dominated by the need for heterogeneous smart things to collect and exchange data which will serve the world's safety and entertainment. This paper summarizes the plethora of some research efforts seeking to kick-off the adopting and supporting 5G technologies in a vehicular environment. In fact, the proper inauguration of a full-fledged, smart, and efficient ITS is foreseen to support the legitimate realization of the next generation 5G network by providing several benefits including easier content sharing and efficient computation offloading. Vehicle manufacturers as well as industrial partners are invited to join forces with research experts in order to expedite the investigation of vehicular networking which will play a vital role in realizing the IoT paradigm and supporting the 5G technologies.

References

[1] L. Davidson, "How connected cars are driving the internet of things," Technical Report, The Telegraph, 2015.

[2] J. Frazer, "Smart cities: Vehicle to infrastructure and adaptive roadway lightning communication standards," Technical Report, GridAptive Technologies, 2012.

[3] SmarTech Markets Publishing LLC, "Additive manufacturing for the drone/UAV industry: an opportunity analysis and ten-year forecast," Charlottesville VA, USA, 2017.

[4] S. Pierce, "Vehicle-infrastructure integration (vii) initiative: benefit-cost analysis: pre-testing estimates," March 2007.

[5] K. Tweed, "Why cellular towers in developing nations are making the move to solar power," Scientific American, 2013.

[6] V. Chamola *et al.*, "Solar powered cellular base stations: current scenario, issues and proposed solutions," IEEE Communications Magazine, 54(5), 2016.

[7] R. Atallah *et al.* "Energy harvesting in vehicular networks: a contemporary survey," IEEE Wireless Communications Magazine, 23(2), 2016.

[8] Y. He *et al.*, "On WiFi offloading in heterogeneous networks: Various incentives and trade-off strategies," IEEE Communications Surveys and Tutorials, 18(4), 2016.

[9] I. Ku *et al.,* "Towards software-defined VANET: Architecture and services," 2014 13th Annual MED-HOC-NET, 2014.

[10] K Zheng, Q Zheng, P Chatzimisios, W Xiang, Y Zhou, "Heterogeneous vehicular networking: a survey on architecture, challenges, and solutions," IEEE communications surveys & tutorials 17 (4), 2377-2396.

Ribal Atallah received the B.S. degree in Computer and Communication Engineering with high distinction from Notre-Dame University, Lebanon in 2009. In 2012, he graduated with an M.S.E degree in Computer Engineering from the Lebanese American University, Lebanon. In April 2017, Dr. Atallah received his PhD degree in Information and Systems Engineering from Concordia University, Montreal, Canada. His current research interests include Intelligent Transportation Systems, Queueing Theory Modelling, Artificial Intelligence, Smart Grid Cyber Security, and Deep Learning.

Chadi Assi is currently a Professor at Concordia University, Montreal, Canada. He received his Ph.D. degree from the Graduate Center, City University of New York (CUNY), in 2003. Dr. Assi received the prestigious Mina Rees Dissertation Award from CUNY for his research on WDM optical networks. His current research interests are in the areas of network design and optimization, and network modelling. Dr. Assi is on the Editorial Board of the IEEE Transactions on Vehicular Technology, IEEE Transactions on Communications, and IEEE Communications Surveys and Tutorials and he is a senior member of the IEEE.

Cognitive Vehicular Ad Hoc Networks

Yuanwen Tian, Jun Yang, Jiayi Lu, Chao Han, and Zeru Wei
School of Computer Science and Technology, Huazhong University of Science and Technology, China
{yuanwen_tian, junyang.cs, jiayilu.epic, chaohan.epic, zeruwei.epic}@qq.com

Introduction

Currently, the vehicle industry is going through a huge technological revolution. With the rapid development of wireless mobile communication technology, the concept of vehicular ad hoc networks (VANETs) is proposed as a way to improve road safety and improve transportation efficiency. Since then, a lot of related research has been done, such as vehicular fog computing in [1]. According to an investigation [2], driving errors on road would evidently decline if we utilize vehicular communication and self-driving technology. However, traditional VANETs cannot fully satisfy the strict requirements of future autonomous driving scenarios, such as high speed mobility, delay sensitivity, seamless connectivity, data privacy and resource constraints [3]. On the other hand, cognition and autonomicity are enabling paradigm for strict requirements of mobile system [4][5]. [6] presents a comprehensive view of cognitive computing and Cloud/IoT. Enabled by cognitive computing, the framework of cognitive vehicular ad hoc networks is proposed to tackle the above challenges.

2. Framework of Cognitive Vehicular Ad Hoc Networks

Due to the high speed mobility of transportation systems, the reliability in traditional VANETs is vulnerable. Therefore, we propose a five-layer framework.

2.1 Sensing layer

Sensing layer is in charge of collecting and pre-processing for multi-source heterogeneous big data. These data come from space-time data in physical space, and network traffic and resource distribution data in network space. Joint analysis will be conducted both in physical space and network space.

2.2 Communication layer

In order to be adapted to requirements of applications with different timeliness, cloud/edge hybrid architecture is adopted in communication layer. Most of the driving data need timely local processing and computing, exploiting the real-time communication between intelligent devices on VANETs and edge cloud.

2.3 Cognition layer

Data cognitive engines are deployed at cognition layer. The data cognitive engine collects data from both physical data space and network data space provide the data to the data cognitive engine processes and analyzes heterogeneous data flows through cognitive analysis methods (machine learning, deep learning, data mining, pattern recognition etc.). In detail, data cognitive engine is able to conduct cognition of user tasks by use of data collected, e.g., driving behavior model analysis, emotion analysis, road condition investigation, etc.

2.4 Control layer

Control layer is the key factor determining system performance as exponentially increased data need to be processed and corresponding strategies need to be provided. Resource cognitive engines deployed on edge support delay sensitive data management while those deployed on cloud conduct network optimization in a centralized way through effective utilization of the global information. Enabled by technologies like NFV, SDN, SON and network slicing, the main function of resource cognitive engines are to manage and dispatch network resources.

2.5 Application layer

Application layer involves coordination and cooperation among multiple parties, including manufacturer of vehicles, mobile communication operator, social networking services provider, etc. Typically, two main categories are customized application services and intelligent transportation applications.

3. Vehicular Cognitive Applications

In recent years, the quantity of mobile intelligent device is increased [7]. Under the environment of vehicle-mounted edge cloud, the strict requirements on latency and reliability of the majority of mobile intelligent devices can be met. NB-IoT technology can also enhance the seamless connection among numerous devices [8]. Meanwhile the mobile intelligent device can enhance the user experience of vehicle-mounted environment, provide the convenient channel

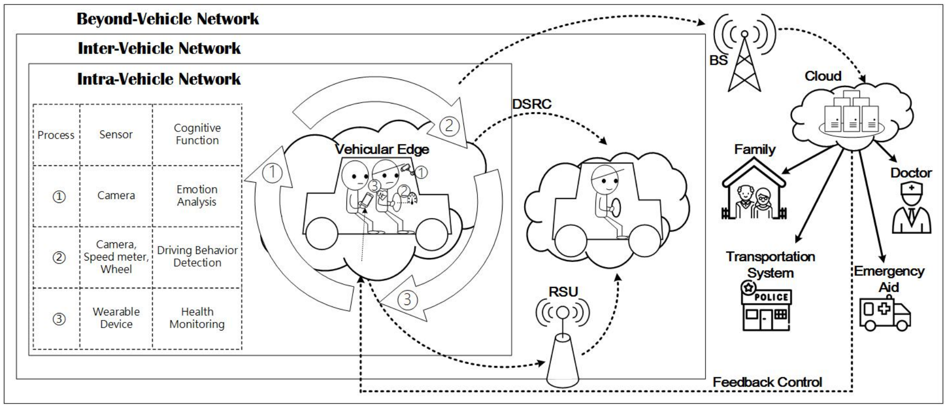


Figure 1. Mobile Healthcare Scenario

of information, and facilitate other aspects of people's life based on different applications.

In the case of mobile healthcare scenario, the passenger and driver fail to understand the mutual healthy conditions under the traditional driving environment, which greatly threatens the safety in the case of health emergency. To improve such situation, cognitive vehicular ad hoc networks carry out the emotion analysis, driving behavior surveillance, and physical health surveillance (Figure 1). The camera detects state of the driver, along with the data collected by other intelligent sensors. The vehicle-mounted edge assesses the health condition of each user by the data cognitive engine. [9] provides machine learning methods on disease prediction problems, which enables mobile health analysis. If the driver suddenly feels unwell, vehicular edge will perceive the condition of the driver timely by smart clothing and give an alarm to the nearby vehicles and cloud. The cloud will dispatch more resources to carry out more comprehensive condition analysis. At the same time, the cloud contacts the ambulance, doctor and driver's home [10] and delivers the analysis result to the doctor timely, so that user's survival ratio can be improved. Under the background of 5G, a cognitive system is established in [11] to improve the quality of healthcare.

4. Conclusion

This letter proposed the framework of cognitive vehicular ad hoc networks consisting of five layers, namely, sensing layer, communication layer, cognition layer, control layer and application layer. It is noted that in the cognition layer, data cognitive engine is used to analyze real-time data and in control layer, resource cognitive engine is used to allocate network resources. Then we presented a typical cognitive application scenario in healthcare field. Equipped with both intelligence and connectivity, this novel framework has great potentiality in future autonomous driving scenarios.

References

[11] X. Hou, Y. Li, M. Chen, D. Wu, D. Jin, S. Chen, “Vehicular Fog Computing: A Viewpoint of Vehicles As the Infrastructures,” IEEE Trans. Vehicular Technology, vol. 65, no. 6, pp. 3860–3873, 2016.

[12] D. J. Fagnant and K. Kockelman, “Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations,” Transp. Res. Part Policy Pract., vol. 77, pp. 167–181, Jul. 2015.

[13] Zheng, et al “Stochastic performance analysis of a wireless finite-state Markov channel," IEEE Transactions on Wireless Communications, vol. 12, no. 2, pp. 782-793, 2013

[14] C. Savaglio and G. Fortino, “Autonomic and Cognitive Architectures for the Internet of Things,” in Int. Conf. on Internet and Distributed Computing Systems, 2015, pp. 39–47.

[15] C. Savaglio, G. Fortino, and M. Zhou, “Towards interoperable, cognitive and autonomic IoT systems: An agent-based approach,” Internet of Things (WF-IoT), 2016 IEEE 3rd World Forum on, 2016, pp. 58–63.

[16] K. Hwang, M. Chen, Big Data Analytics for Cloud/IoT and Cognitive Computing, Wiley, U.K., ISBN: 9781119247029, 2017.

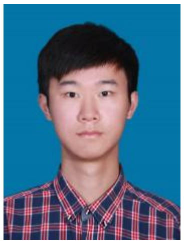
[17] Cisco White paper, “Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper,” Mar. 2017.

[18] M. Chen, Y. Miao, and K. Hwang, “Narrow Band Internet of Things,” IEEE Access, vol. 5, pp. 20557–20577, 2017.

[19] M. Chen, F. Herrera, and K. Hwang, “Human-Centered Computing with Cognitive Intelligence on Clouds,” IEEE Access, DOI: 10.1109/ACCESS.2018.2791469, 2018.

[20] M. Chen, J. Yang, X. Zhu, X. Wang, M. Liu, and J. Song, “Smart Home 2.0: Innovative Smart Home System Powered by

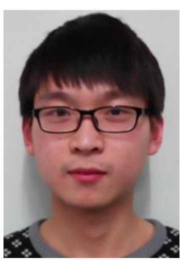
Botanical IoT and Emotion Detection," Mobile Networks and Applications, vol. 22, pp. 1159–1169, 2017.
[21] M. Chen, J. Yang, Y. Hao, S. Mao, K. Hwang, "A 5G Cognitive System for Healthcare," Big Data and Cognitive Computing, vol. 1, no. 1, DOI:10.3390/bdcc1010002, 2017.



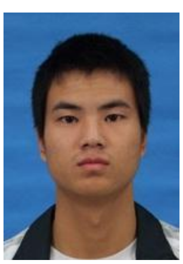
Yuanwen Tian will receive his Bachelor degree from School of Electrical and Electronic Engineering, Huazhong University of Science and Technology (HUST), China, in June 2019. He joined Embedded and Pervasive Computing (EPIC) Lab in 2016, supervised by Professor Min Chen. His present research interests include cognitive computing, machine learning, IoT, big data analytics, etc.

Jun Yang received Bachelor and Master degree in Software Engineering from HUST, China in 2008 and 2011, respectively. Currently, he is a Ph.D candidate at Embedded and Pervasive Computing (EPIC) Lab in School of Computer Science and Technology, HUST. His research interests include cognitive computing, software intelligence, Internet of Things, cloud computing and big data analytics, etc.

Jiayi Lu received the B.S. degree in College of Computer Science and Technology from Xiamen University, Xiamen, China in 2016. Currently, she is a Master. candidate in School of Computer Science and Technology, HUST since 2016. Her research interests include big data, cloud computing and machine learning.



Chao Han was graduated from the school of Information Science and Engineering, Lanzhou University in 2016 and get a bachelor's degree of engineering. Currently, he is a Master. candidate at Embedded and Pervasive Computing (EPIC) Lab in School of Computer Science and Technology, HUST since 2016. His research interests include mobile cloud computing, big data and IoT, etc.



Zeru Wei was graduated from the school of Optical and Electronic Information, Huazhong University of Science and Technology in 2016 and get a bachelor's degree of engineering. Currently, he is a Master. candidate at Embedded and Pervasive Computing (EPIC) Lab in School of Computer Science and Technology, HUST since 2016. His research interests include deep learning and AI, mobile cloud computing, big data and IoT.

Towards Interest Broadcast Mitigation in Named Data Vehicular Networking

Syed Hassan Ahmed
Department of Electrical and Computer Engineering, University of Central Florida, Orlando, FL 32816, USA
Email: sh.ahmed@ieee.org

. Introduction

The rapid growth in Internet traffic has triggered a plethora of research and development projects in the wide domain of communications. Today, we prefer to use higher bandwidth and expect an excellent quality of experience (QoE) in the communication technologies ranging from cellular, Wi-Fi, WiMAX, and Bluetooth to the Internet of Things (IoT) [1]. Similarly, the past two decades brought us tremendous advancements in the transportation and automation industries, where the assurance of safety and security have become the baseline of what we are perceiving today; for example, autonomous cars, safety/non-safety information dissemination between connected vehicles (V2V), infrastructure-based vehicle communications (V2I), and heterogeneous vehicular networks (VNs). The key applications for VNs include, but are not limited to, traffic conditions, accident warnings, pedestrian collision warning systems, smart parking, auto-braking systems, live video streaming, and live gaming. However, the main technical challenges in VNs are related to the high volatility and dynamicity of vehicles' mobility. Even though the Dedicated Short-Range Communication (DSRC) and Wireless Access Vehicular Environment (WAVE) protocol suites have been playing a sophisticated role in the initial stages of VN implementation, it is hard to ensure low latency, high quality, and secured content or data1 retrieval in a robust manner. Moreover, the DSRC and WAVE protocols are based on the conventional TCP/ IP protocols, originally designed for a single conversation between two end-to-end entities widely known as client and host. Regardless of the applications' motivation (i.e., safety or non-safety), the main purpose of connecting vehicles is to share the content to fulfill the applications' requirements. However, dynamic mobility makes it difficult to have reliable communication of the content between connected vehicles. The main reason is that the current standards were originally proposed for static and quasi- static environments. Even though these standards tend to support mobility and fast content delivery in VNs, the applications still require a destination address to deliver the content. Hence, the communication is contingent on the vehicle's identity (IP and/or medium access control, MAC, address). Therefore, the path establishment, maintenance, and identity assignment in VNs are challenging and generate much overhead. On the other hand, from a non-safety application's point of view, we require content retrieval secure and efficient irrespective of the identity and location of the actual provider or producer.

Here comes the role of Future Internet Architectures, where Named Data Networking (NDN) as an extension of content-centric networks (CCNs) has been merged into VNs (VNDN) as a future networking architecture [2]. VNDN basically assigns a name to the content rather than the device (i.e., vehicles), and that name is used to retrieve the required content. In VNDN, we consider a simplified pull-based communication, where a content requesting vehicle (the consumer) sends an Interest message, and the infrastructure or vehicle with the required content (the provider) sends back the Data message. Interest contains the required content name and unique NONCE value to identify the Interest message and avoid its duplicate transmission. On the other hand, the Data message contains the same content name and the embedded security information (e.g., digital signature) within it. Therefore, instead of securing the connection between consumer- provider node pairs, the security is inherently augmented with the Data. Additionally, VNDN supports multiple interfaces for reliable and quick fetching of the required content. Every NDN enabled vehicle maintains the following 3 basic data structures:

- Content store (CS): This caches data or contents either generated or received by the vehicle.
- Forwarding information base (FIB): It stores the outgoing interface(s) associated with the name prefixes to forward the Interests.
- Pending Interest Table (PIT): This keeps track of the names or name prefixes, NONCEs, and incoming interfaces of the received Interest(s). The entries are kept for a certain period and removed when the Interests are satisfied or their lifetime in the PIT expires.
- NONCE List: It records the NONCEs of all the pending entries of the satisfied Interests from the PIT to prevent an Interest loop. All entries are timestamped and purged after a certain time.

An Interest is uniquely identified by the NONCE plus content Name. A node receiving an Interest first checks the NONCE list, to check whether the Interest has been recently satisfied or not. If no entry is found in the NONCE list, a record of the received Interest is scanned in the PIT to verify whether the Interest is still pending or not. The entry in the PIT shows that the Interest has already been forwarded. On the contrary, the NONCE and Name are stored in the PIT along with the Interface from where the Interest was received (called InFace). The PIT entry is purged once the Interest is satisfied. If a node receives multiple copies of the pending Interest, the InFace(s) and other information are aggregated in the PIT record with the same Name. In a scenario where a node receives a Data message, it first checks the PIT record. Based on the PIT search result, the Data message is either forwarded, if there is an entry in the PIT, or dropped otherwise. The satisfied Interest's record is removed from the PIT, and NONCE(s) information is stored in the NONCE list. An Interest loop occurs when a node receives another copy of the satisfied Interest from the path with large delay and can be avoided by checking the Interest's record in the NONCE list. This operational mechanism of Interest and Data messages is summarized in Fig. 1.

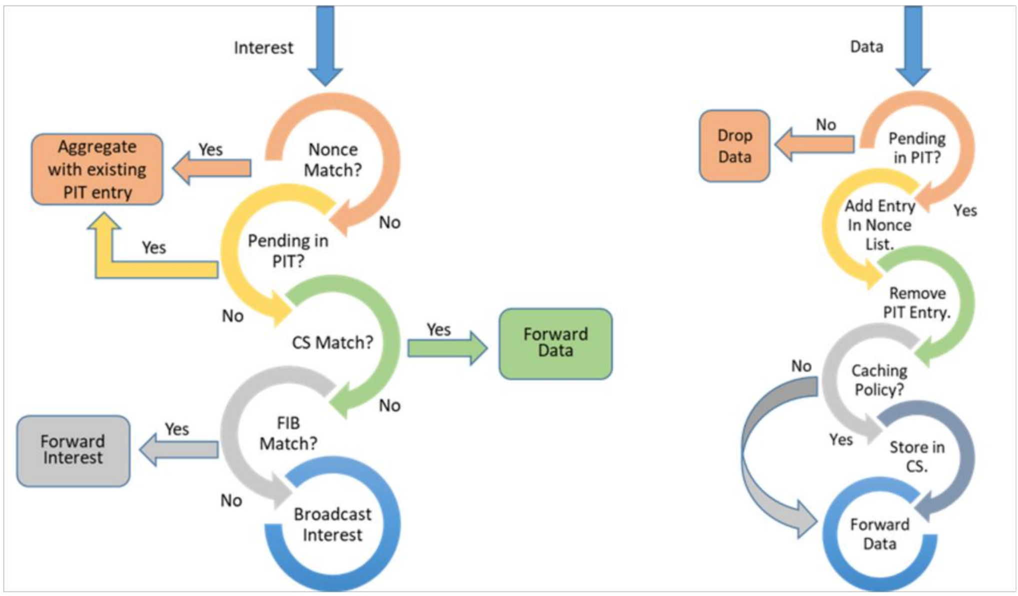


Figure 1. Interest & Data Packets Traversal in Vehicular Named Data Networks

2. Research Advancements towards Interest Broadcast Mitigation

Nevertheless, problem occurs when we overload the network by disseminating Interest packets for every single chunk of the Data. Moreover, the retransmission of the Interest packet is directly related to the PIT lifetime i.e. upon the expiration of the PIT lifetime, e.g. 4 seconds in many implementations, the Interest is retransmitted. Such retransmissions create broadcast storm. Few of the recent efforts to mitigate Interest broadcast are as follows:

2.1. RUFS:

In [3], the authors proposed Robust Forwarder Selection (RUFS), in which any consumer/forwarder can select only one vehicle among the immediate neighboring vehicles for interest forwarding. Each vehicle maintains a local data structure which contains the list of satisfied interests' information by that particular vehicle, termed Recent Satisfied List (RSL). The RSL is exchanged periodically using beacon messages with the neighboring vehicles. In addition, the FIB structure is replaced with a Neighbors Satisfied List (NSL) structure, which is updated by each vehicle periodically on every beacon message received. The NSL at each of the vehicles is used to aggregate the RSLs received from the neighboring vehicles. The consumer or forwarder applies a multi-criteria decision method to out-rank the next ideal forwarder, using the multiple properties of each neighboring vehicle in the NSL as the selection criteria. The criteria used for a particular content are; time since the recent satisfaction of the content, content received hop-count, vehicle velocity. Furthermore, authors introduce a new criterion, the Interest Satisfaction Rate which is the ratio of total satisfied content to the total requested contents, by the vehicle. RUFS forwarder selection process limits the interest flooding in the dynamic VN scenario. How- ever, it may face issues when a single forwarder is selected by multiple vehicles, leading to collision, congestion and de- lay. Also, the additional overhead in the network caused by the beacon messages should be optimized.

2.2. CODIE:
Since Data packets carry the actual content, they are generally much larger than Interest packets and more likely to cause congestion. Similarly, the immediate neighbor(s) of a provider, after receiving the Data packet, attempt(s) to send the Data back to the consumer and thus waste the bandwidth and cause congestion, and additional Data copies are traversed. To tackle this, in [4], the authors proposed a controlled Data packet propagation algorithm named as CODIE for VNDN to cope with the given issue. In CODIE, while broadcasting an Interest packet, each node includes hop counter h. After receiving the Interest packet, if the intermediate node is not a provider, it increments h, creates PIT entry along with h, and then forwards the Interest packet. Once the Interest packet reaches its provider, the provider increments h one last time and includes the latest value into the "data dissemination limit" (DDL) field in Data packets. The purpose of including DDL in Data packet(s) is to ensure that the packet does not go further than the actual consumer, and using DDL, we limit the additional copies of the Data/Content.

2.3. DIFS:
Like aforementioned, in VNDN, the epidemic Interest forwarding results in traffic congestion due to the broadcast storm. In order to cope this, the authors in [5] propose a distributed Interest Forwarder selection (DIFS), where two forwarders in opposite direction are selected to forward/rebroadcast the Interest along the highway. The purpose of selecting two forwarders is to spread the Interest packet(s) in both forward and backward directions via best available intermediate vehicles. Thus, alleviating the need for hop-by-hop geo-location information and data retrieval rate sharing. For this purpose, the DIFS lets each vehicle to utilize multiple attributes of the neighboring vehicles and calculate the eligibility of being a forwarder. The proposed DIFS ensures that from among the neighboring vehicles only those vehicles may forward Interest packets that have maximum connectivity time and good link quality with the consumer so that the Data retrieval process avoids any additional delays. This also helps in controlling the number of retransmissions.

3. Conclusion
In this article, we first introduce Named Data Networking for vehicular communications followed by a bird's eye view on trending issues specifically the Interest Forwarding and Broadcast Storm due to the epidemic Interest flow. Further, we summarize the recent efforts of mitigating the Interest retransmissions and thus bringing robustness in the content retrieval in future vehicular networking technologies.

References

[22] A. Ioannou and S. Weber, "A Survey of Caching Policies and Forwarding Mechanisms in Information-Centric Networking," in IEEE Communications Surveys & Tutorials, vol. 18, no. 4, pp. 2847-2886, Fourth quarter 2016.

[23] M. Amadeo, C. Campolo and A. Molinaro, "Information-centric networking for connected vehicles: a survey and future perspectives," in *IEEE Communications Magazine*, vol. 54, no. 2, pp. 98-104, February 2016.

[24] Syed Hassan Ahmed, Safdar Hussain Bouk, and Dongkyun Kim, "RUFS: RobUst forwarder selection in vehicular content-centric networks," IEEE Communications Letters, Vol. 19, Issue. no. 9, 1616-1619, 2015.

[25] Syed Hassan Ahmed, Safdar Hussain Bouk, Muhammad Azfar Yaqub, Dongkyun Kim, Houbing Song, and Jaime Lloret, "CODIE: Controlled data and interest evaluation in vehicular named data networks," IEEE Transactions on Vehicular Technology, Vol. 65, Issue. no. 6, pp. 3954-3963, 2016.

[26] Syed Hassan Ahmed, Safdar Hussain Bouk, Muhammad Azfar Yaqub, Dongkyun Kim, Houbing Song, "DIFS: Distributed Interest Forwarder Selection in Vehicular Named Data Networks," in *IEEE Transactions on Intelligent Transportation Systems*, vol. PP, no. 99, pp. 1-5, 2017.

Syed Hassan Ahmed (www.hassanonline.us) completed his B.S in Computer Science from Kohat University of Science & Technology (KUST), Pakistan and Masters combined Ph.D. Degree from School of Computer Science and Engineering (SCSE), Kyungpook National University (KNU), Republic of Korea. In summer 2015, he was also a visiting researcher at the Georgia Tech, Atlanta, USA. Collectively, Dr. Hassan authored/co-authored over 100 international publications including Journal articles, Conference Proceedings, Book Chapters, and 02 books. From the year 2014 to 2016, he consequently won the Research Contribution awards by SCSE at KNU, Korea. In 2016, his work on robust content retrieval in future vehicular networks lead him to win the Qualcomm Innovation Award at KNU, Korea. Currently, Dr. Hassan is a Post-Doctoral Fellow in the Department of Electrical and Computer Engineering, University of Central Florida, Orlando, FL, USA. His research interests include Sensor and Ad hoc Networks, Cyber-Physical Systems, Vehicular Communications and Future Internet.