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Situational Awareness of COVID Pandemic data using Virtual Reality

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Abstract

Situational awareness provides the decision making capability to identify, process, and comprehend big data. In our approach, situational awareness is achieved by integrating and analyzing multiple aspects of data using stacked bar graphs and geographic representations of the data. We provide a data visualization tool to represent COVID pandemic data on top of the geographical information. The combination of geospatial and temporal data provides the information needed to conduct situational analysis for the COVID-19 pandemic. By providing interactivity, geographical maps can be viewed from different perspectives and offer insight into the dynamical aspects of the COVID-19 pandemic for the fifty states in the USA. We have overlaid dynamic information on top of a geographical representation in an intuitive way for decision making. We describe how modeling and simulation of data increase situational awareness, especially when coupled with immersive virtual reality interaction. This paper presents an immersive virtual reality (VR) environment and mobile environment for data visualization using Oculus Rift head-mounted display and smartphones. This work combines neural network predictions with human-centric situational awareness and data analytics to provide accurate, timely, and scientific strategies in combatting and mitigating the spread of the coronavirus pandemic. Testing and evaluation of the data visualization tool have been done with real-time feed of COVID pandemic data set for immersive environment, non-immersive environment, and mobile environment.

1. Introduction

Visualization bridges the gap between quantitative content of data and human intuition. Humans have an inherent capability of knowledge discovery and the ability to perform effective and flexibly visual explorations. Visualization is an integral part of the data mining process. When the data is big, different data analysis methods and approaches are used to find inherent patterns and links. However, sometimes a human in loop intervention is needed to find new links and relationships that the existing algorithms cannot provide. Immersive virtual reality provides the “sense of presence” in the virtual world and gives the ability to discover new relationships by visual inspection. It is important in the data preparation process that missing or anomalous data can be identified by inspection, and removed from the analysis.

One of the goals of this work is to investigate the merging of immersive virtual reality (VR) and data science for advanced visualization. VR and immersive visualization involve interplay between novel technology and human perception to generate insight into both. We propose to use immersive VR for exploring the higher dimensionality and abstraction that are associated with big data. VR can use an abstract representation of high-dimensional data in support of advanced scientific visualization. We believe that new ways of visualization will promote new ways of interaction. The immersive VR environments will be used to design new graphical user interfaces for various data applications. Visual analytics approaches can be transferred to the immersive environments and expanded with the new interaction 3D techniques. For example, visualizing excel data creates 3D charts that one can view in an immersive environment. Our proposed environments in figure 1 show that one can throw 3D charts on the table in a meeting to explain and investigate data typically hard to understand and convey. We hope that natural interaction mechanisms will allow a new visual analytics method where one can group, sort, filter, zoom, and interact with all kinds of data collections. Our research agenda is three folds

- Human cognitive limitations in terms of Big Data Visualization.
- Applying Virtual reality interaction for Big Data Visualization.
- Challenges and benefits of the proposed VR visualization approach.

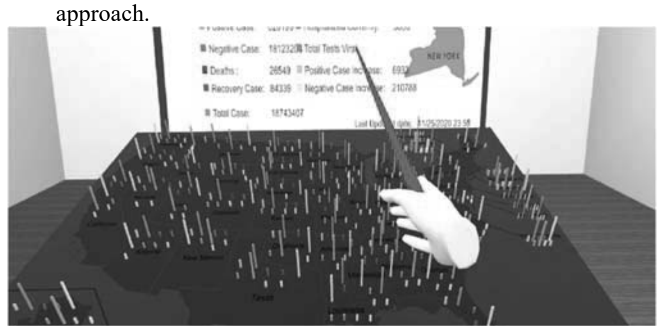

Figure 1. Data visualization tool to represent COVID pandemic data on top of the geographical map

We have combined virtual reality interaction techniques and 3D geographical information representation to enhance the visualization of situational impacts as shown in Figure 1. The data visualization tool is developed using the Unity gaming engine. It provides the capability to toggle on/off the different variables related to the COVID pandemic on top of the USA map. The map displays nine different variables related to COVID data for each state such as

- Positive Cases
- Negative Cases
- Deaths
- Recovery Cases
- Total Cases
- Hospitalized Currently
- Total Tests Viral
- Positive Cases Increase
- Negative Case Increase

For all nine variables, nine checkboxes were implemented as shown in figure 1. These nine checkboxes provide the capability to enable and disable the bars on the map. This provides the user a way to compare data for the different states. our goal is to provide an intuitive understanding of COVID data for different states and to provide insights for decision making. The user is also able to select a state and view its related information in detail. We summarize the key features of mobile, immersive environments like the following

- Input: head-mounted display device such as oculus rift, HTC vive, etc., multi-sensory input such as eye-tracking, voice, and gesture that work separately or with controllers.
- Output: immersive environments with vision and sound, for transformation, advanced interaction, and collaboration experiences.

The rest of the paper is organized as follows: Section 2 discusses the related work in data visualization as well immersive VR; Section 3 details the system architecture of the data visualization tool; Section 4 describes the implementation of the application in three phases; Section 5 describes the results of the user study and evaluation of the 3D data visualization tool, and Section 6 discusses the drawn conclusions and proposed future work. Finally, Section 5 states acknowledgments.

2. Related Work

Visual analytics and information visualization researchers have explored various data for visualization applications in 3D [1]. Immersive visualizations have utilized scatter plots [2], parallel coordinates [3], and networks [4] for data visualization. Filonik et al. [5] have proposed a GPU-based framework called Glance, which focuses on rendering fast and effective abstract visualizations in AR and VR. On the Other hand, Donalek et al. [6] have developed a framework called as iViz, which provides a GUI for a collaborative VR analytics environment. Virtualitics [7] is another commercial immersive and collaborative visualization platform for three dimensional visualizations. Data visualization tool has been developed by including both conceptual and data-driven information real-time data visualization [8].

Sharma et al. [9-11] have presented a real-time data visualization for location based navigation in multilevel spaces by generating ARI visualizations with contextualized communication of evacuation plans. HoloLens has also been used to create situational awareness for indoor evacuations [12-14]. Sanfilipa et al. [15] have introduced InfoStar, an adaptive visual analytics platform for mobile devices. Virtual reality environments have been effective in many scientific applications such as brain tumor analysis [16], archaeology [17], geographic information systems [18], geosciences [19], education [20], or emergency response [21].

3. Situational Awareness and Data Analytics

We have incorporated Oculus Rift to allow immersive analytics are the low-cost virtual reality HMDs (Head-mounted Display). It allows for immersive 3D visualization, so that the user is physically embedded in the real world. We are exploring how data extracted from real-time updated API can be embedded on top of geographical maps for visual analytics. Figure 2 shows the system architecture of our proposed 3D data visualization tool. The COVID data from the cloud database is extracted and populated on the USA geographical map in the form of bar graphs. The data visualization tool is deployed in oculus rift s and smart-phones with the help of multiple scripts to filter the raw data. The tool gives an enriched immersive experience to the user. The proposed 3D data visualization tool was developed for visualizing the real-time COVID data set in an immersive environment, non-immersive environment, and mobile environment.

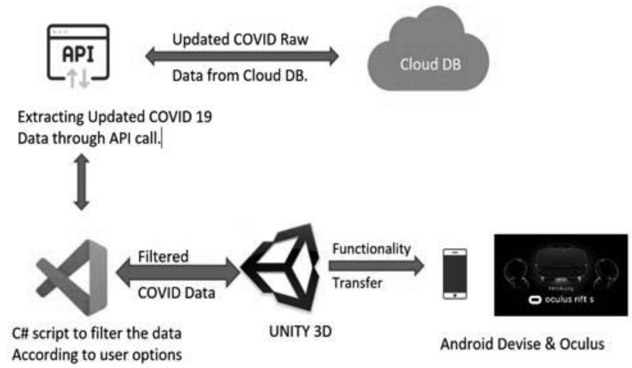

Figure 2. System Architecture

The implementation of the data visualization tool was done in three phases:

3.1 Phase 1: Modeling

Phase 1 of the data visualization tool consisted of modeling the 3 D environment using 3Ds max and google sketch up. The environment was modeled to scale and imported real-time textures. The environment included adding 3D models of furniture in office rooms, labs and lecture halls such as tables, computers, mouse, and furniture to add adding realism. After modeling the 3D environment, it was exported to unity 3D gaming engine.

3.2 Phase 2: Exporting to Unity 3D and 3D data visualization

In phase 2, the modeled environment was exported from Google Sketch-to Unity 3D gaming engine. Initially, functionalities were added to provide the user the flexibility to navigate in the environment.

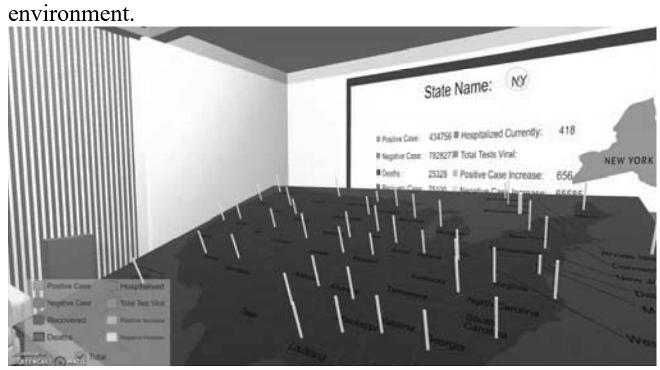

Figure 3. 3D data visualization in a non-immersive environment

A geographical map of the USA showing 50 states was displayed on the table as shown in figure 3. On top of the map, data from real-time API for COVID pandemic data was extracted and displayed as bar graphs for each state. The data from API extracted nine variables related to COVID pandemic data (Positive Cases, Negative Cases, Deaths, Recovery Cases, Total Cases, Hospitalized Currently, Total Tests Viral, Positive Cases Increase, Negative Case Increase) for each of fifty states. The height of the bar graphs was set to a unit and was linked with the script to increase height according to the number of cases. This data from the database was extracted with the help of API calls. When the 3D data visualization application is launched, the API call automatically extracts the updated data. Initially, the raw data contained unwanted data and it was filtered with the help of scripts written to extract the data and display it in the form of bar charts on the map. To implement the interaction with data, check boxes were implemented to allow toggling on/off the different variables on the graph. The checkboxes allowed the user to enable or disable the bars on the map for each state. This allows the user to customize the data visualization according to user choices by interacting with the checkboxes. Another functionality implemented is the ability to click each state like a button. Clicking each state displays the data related to each state on the display screen in front of the table. This allows for a more detailed view of the data related to each state.

3.3 Phase 3: Oculus integration and controller simulation

In phase 3 C# scripts were developed to integrate Oculus Rift S and the Oculus Touch controllers in the environment. The users were able to navigate in the environment and interact with objects and menus using oculus touch controllers. The Oculus Touch headset allowed users to navigate and experience the environment with full immersion. Oculus Touch controllers also give haptic feedback to the user when using objects such as guns and selection laser pointer. Besides, C# scripts were added to the user-controlled agents to give users the ability to communicate with the menu and laser pointer for selection as shown in figure 4.

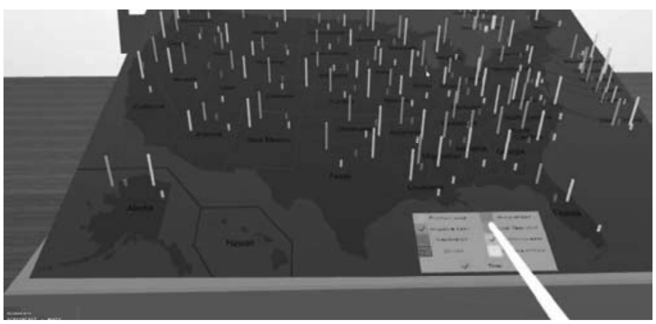
Figure 4. 3D data visualization in an immersive environment

The graphical user interface was developed for the immersive environment using Oculus Rift S HMD and controllers, a non-immersive environment using mouse and keyboard, and a mobile environment using touch controllers. Initially, the non-immersive GUI was built and a first-person controller was included in the environment. This allowed the user to move in the environment with the help of a mouse and keyboard. An interaction and navigation script was implemented for the first person controller in the environment. The interaction script allowed the user to interact with the map by toggling on/off the checkboxes for the nine variables extracted from the COVID data. After the development, an executable file was generated sot that it can run on any Windows device. Later, an immersive GUI was built for Oculus Rift S, so that the user can interact in the virtual environment. Scripts were developed for oculus rift touch controllers for navigation and interaction with 3D objects in the environment.
The interaction in the non-immersive environment through mouse and keyboard was replaced with Oculus controllers, and the first person was replaced with an oculus camera. This allowed the camera movement by following the oculus head movement. Functionality for the user to trigger a laser beam and click check-boxes as well as click each state was added to the Oculus touch controllers. Finally, a mobile GUI was developed for smart-phones. Two touch controllers were implemented on the GUI screen for navigation in the environment. For testing the Samsung S9 and Samsung Galaxy Note 9 devices were used. The specifications of the device include OS: Android 9.0, CPU: Octa-Core, GPU: Mali-G7, RAM: 4GB. Two touch controllers implemented on the GUI screen for navigation acted like joystick controllers. The left side controller was used for navigation in the X and Y axis, while the right-side controller was used for navigation in the Y and Z-axis. After implementing the scripts successfully, an APK file was created for the android smart-phone. This APK was used for the installation of the 3 D visualization application in the mobile device.

4. Data Visualization

The prototype development was done using the Unity 3D gaming engine. We extracted exploring data from real-time updated API for COVID pandemic and then embedded it on top of geographical maps for visual analytics. Proper lighting was added to the environment as it can affect us on both a cognitive and affective level. The objective of this work was to demonstrate the data visualization of the COVID pandemic in real-time for the fifty states in the USA by including stacked bar graphs, geographic representations of the data, to increase situational awareness of the COVID-19 pandemic.

4.1 Bar Graphs

Bar charts are the simplest graphs that are used to visualize simple x, y plots of data for numerical comparisons. Bar charts are capable of interpreting simple information. However, in the business world, data analyst uses the color coding scheme and data labeling on the bar chart to enhance the readability of data to the users. However, bar charts are very basic and one-dimensional visualization that only meets the basic requirement of complex data. In today's growing needs of data with multi-dimensional attributes, using bar graphs is not sufficient to deal with complex data sets and it also not utilizes the screen space efficiently. But bar charts are still useful because their shape create strong visual attention to users at first glance than other visualization techniques. In this work, we have presented bar graphs with oculus controller to combine the bar chart visualization with a zooming feature that allows users to view the details of a particular bar chart in an effectively.

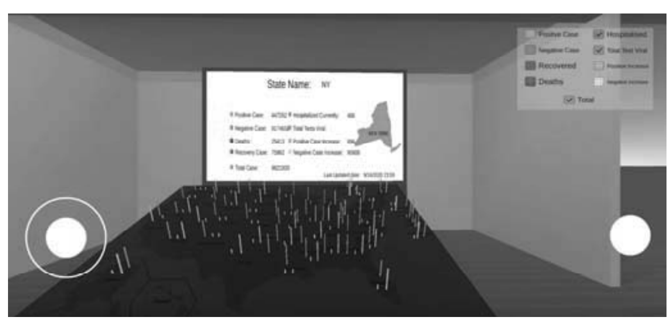

Figure 5. 3D data visualization in a mobile environment

Generally, bar charts are used to visualize volume data, count data, and simple statistics. The bar charts are recognized by their variable rectangle blocks with color-coded scheme to create a visual impact. For example, bar charts highlight the minimum and maximum data at a glance without forcing the user to search for background information such as labels. Figure 5 shows the bar graphs that represent data as rectangular bars with height proportional to the values that they represent. For each variable, the bar graphs are arranged for each state on the map. The map displays nine different variables related to COVID data as bar graphs with different colors. The user can toggle the checkboxes on/off to visualize the variables for COVID related statistics.

5. Conclusions

The primary goal of this research is attempting to extend the capability of original bar graphs to visualize the COVID pandemic dataset with multiple dimensions that meet the demand for visualizing growing complex dataset and enhancing the user understanding. The benefits of our proposed work multifold:

- Providing a data visualization tool for immersive visualization and visual analysis.
- Suggesting key features that immersive analytics can provide with situational awareness and in loop human intervention for decision making.
- Demonstrating data visualization with real-time feed of COVID -19 data set for immersive environment, non-immersive environment, and mobile environment.

Overall, our VR data visualization tool was perceived as satisfying and successful in visualizing real time COVID pandemic data and gave insights during the comparison of data with different states. VR helps in engaging the user for more effective data analysis with more human-in loop interaction. We, therefore, see a potential for VR applications involving multi-dimensional data that require users' engagement for analysis of data. In conclusion, this paper proposed a new data visualization tool with the oculus viewing to increase the immersive capability of the traditional bar charts in representing complex COVID pandemic data.

We aim to evaluate visualizations with participants by incorporating a more fine-grained analysis of insights (e.g. coding and coloring a variable to give insight that differentiates between outliers, distribution, etc.). We are also interested in extending our VR data visualization tools to enable collaborative, multi-user data exploration and to explore the impact of VR on collaborative analytics tasks, in comparison with traditional 2D visualizations.

Acknowledgments

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References

[1] K. Reda, A. Febretti, A. Knoll, J. Aurisano, J. Leigh, A. Johnson,M. Papka, and M. Hereld, "Visualizing large, heterogeneous data in hybrid-reality environments, "IEEE Computer Graphics and Applica-tions, vol. 33, no. 4, pp. 38–48, (2013).

[2] B. Bach, R. Sicat, J. Beyer, M. Cordeil, and H. Pfister. The hologram in myhand: How effective is interactive exploration of 3D visualizations in immersive tangible augmented reality? IEEE Transactions on Visualization and Computer Graphics, 24(1):457–467, Jan 2018. doi: 10.1109/TVCG.2017.2745941 (2108).

[3] S. Butscher, S. Hubenschmid, J. M ̈uller, J. Fuchs, and H. Reiterer. Clus-ters, trends, and outliers: How immersive technologies can facilitate thecollaborative analysis of multidimensional data. InProceedings of the CHI Conference on Human Factors in Computing Systems, CHI '18, pp. 90:1–90:12. ACM, New York, NY, USA, 2018. doi: 10.1145/3173574.317366 (2018).

[4] M. Cordeil, T. Dwyer, K. Klein, B. Laha, K. Marriott, and B. H. Thomas. Immersive collaborative analysis of network connectivity: Cave-style or head-mounted display? IEEE Transactions on Visualization and Computer Graphics, 23(1):441–450, Jan 2017. doi: 10.1109/TVCG.2016.25991, (2017).

[5] D. Filonik, T. Bednarz, M. Rittenbruch, and M. Foth. Glance: Generalized geometric primitives and transformations for information visualization in AR/VR environments. In Proceedings of the 15th ACM SIGGRAPH Conference on Virtual-Reality Continuum and Its Applications in Industry - Volume 1, VRCAI '16, pp. 461–468. ACM, New York, NY, USA,doi: 10.1145/3013971.3014006, (2016).

[6] C. Donalek, S. G. Djorgovski, S. Davidoff, A. Cioc, A. Wang, G. Longo,J. S. Norris, J. Zhang, E. Lawler, S. Yeh, A. Mahabal, M. J. Graham,and A. J. Drake. Immersive and collaborative data visualization using virtual reality platforms. In Big Data (Big Data), 2014 IEEE International Conference on, pp. 609–614. IEEE, (2014).

[7] Virtualitics.https://www.virtualitics.com/. Last accessed: Feb (2021).

[8] Sharma, S, Bodempudi, S.T., Reehl, A. " Real-Time Data Visualization to Enhance Situational Awareness of COVID pandemic ", Proceeding of the IEEE International Conference on Computational Science and Computational Intelligence (CSCI'20), Las Vegas, Nevada, USA, Dec 16-18, (2020).

[9] S. Sharma, S, Stigall, J., Bodempudi, S.T., "Situational awareness-based Augmented Reality Instructional (ARI) module for building evacuation", Proceedings of the 27th IEEE Conference on Virtual Reality and 3D User Interfaces, Training XR Workshop, Atlanta, GA, USA, pp. 70-78, March 22-26, (2020).

[10] Stigall, J., Sharma, S, "Evaluation of Mobile Augmented Reality Application for Building Evacuation", Proceedings of ISCA 28th International Conference on Software Engineering and Data Engineering in San Diego, CA, USA, vol 64, pages 109--118, (2019).

[11] Stigall, J., Sharma, S, "Mobile Augmented Reality Application for Building Evacuation Using Intelligent Signs", Proceedings of ISCA 26th International Conference on Software Engineering and Data Engineering (SEDE-2017), pp. 19-24, San Diego,CA, USA, October 2-4, (2017).

[12] Sharma, S, Bodempudi S.T., Scribner D., Grynovicki J., Grazaitis P., "Emergency Response Using HoloLens for Building Evacuation", In Virtual, Augmented and Mixed Reality. Multimodal Interaction. HCII 2019. Lecture Notes in Computer Science, vol 11574, pp 299-311, https://doi.org/10.1007/978-3-030-21607-8_23, Print ISBN 978-3-030-21606-1, Springer, Cham, (2019).

[13] Stigall, J., Bodempudi, S.T., Sharma, S, Scribner, D., Grynovicki, J., Grazaitis, P., "Use of Microsoft HoloLens in indoor evacuation", International Journal of Computers and their Applications, IJCA, Vol. 26, No. 1, March (2019).

[14] Sharma, S., Bodempudi, S.T., "Identifying anomalous behavior in a building using HoloLens for emergency response", IS&T International Symposium on Electronic Imaging (EI 2020), in the Engineering Reality of Virtual Reality, DOI: https://doi.org/10.2352/ISSN.2470-1173.2020.13.ERVR-224, 26 January- 30 January (2020).

[15] Sanfilippo, R.May, G.Danielson, B.Baddeley, R.Riensche, S.Kirby, S.Collins, S.Thornton, K.Washington, M.Schrager, J.V.Randwyk, B.Borchers, and D.Gatchell, "Anadaptive visual analytic splatform for mobile devices, "inSC'05: Proceedings of the 2005 ACM/IEEE conference on Supercomputing, Washington, DC, USA, IEEE Computer Society, p.74, (2005).

[16] S. Zhang, C. Demiralp, D. Keefe, M. DaSilva, D. Laidlaw, B. Green-berg, P. Basser, C. Pierpaoli, E. Chiocca, and T. Deisboeck, “An immer-sive virtual environment for DT-MRI volume visualization applications:a case study,” inProceedings Visualization 2001. IEEE, , pp. 437–440, (2001).

[17] G. Kurillo and M. Forte, “Telearch – Integrated visual simulation environment for collaborative virtual archaeology,” Mediterranean Archaeology and Archaeometry, vol. 12, no. 1, pp. 11–20, 2012.

[18] N. G. Smith, K. Knabb, C. DeFanti, P. Weber, J. Schulze, A. Prud-homme, F. Kuester, T. E. Levy, and T. A. DeFanti, “ArtifactVis2: Man-aging real-time archaeological data in immersive 3D environments,” in Proceedings Digital Heritage International Congress, vol. 1. IEEE, pp. 363–370, (2013).

[19] R. Bennett, D. J. Zielinski, and R. Kopper, “Comparison of Interactive Environments for the Archaeological Exploration of 3D Landscape Data,” in IEEE VIS International Workshop on 3DVis, (2014).

[20] Sharma, S., Ossuetta, E., "Virtual Reality Instructional Modules in Education Based on Gaming Metaphor", IS&T International Symposium on Electronic Imaging (EI 2017), in the Engineering Reality of Virtual Reality, Hyatt Regency San Francisco Airport, Burlingame, California, pp. 11-18(8), DOI: https://doi.org/10.2352/ISSN.2470-1173.2017.3.ERVR-090, 29 January- 2 February (2017).

[21] Sharma, S., Devreaux,P., Scribner, P., Grynovicki, J., Grazaitis, P., "Megacity: A Collaborative Virtual Reality Environment for Emergency Response, Training, and Decision Making, IS&T International Symposium on Electronic Imaging (EI 2017), in the Visualization and Data Analysis, Proceedings Papers, Burlingame, California, pp. 70-77(8), DOI: https://doi.org/10.2352/ISSN.2470-1173.2017.1.VDA-390, 29 January- 2 February (2017).

[22] Dugas, Norman. "Active Shooter Training: A Recommended Addition to the Basic Peace Officer Course.", (2017).

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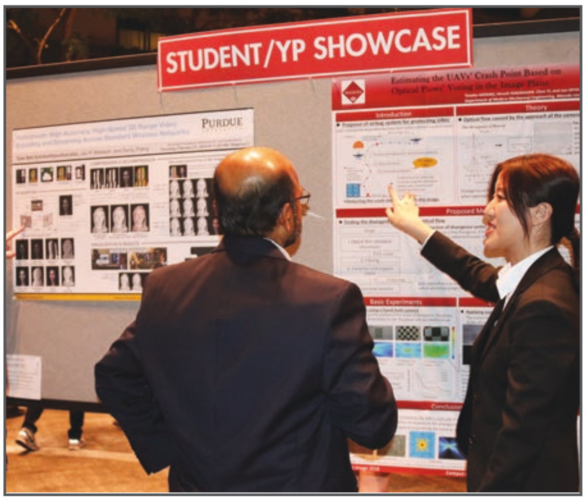

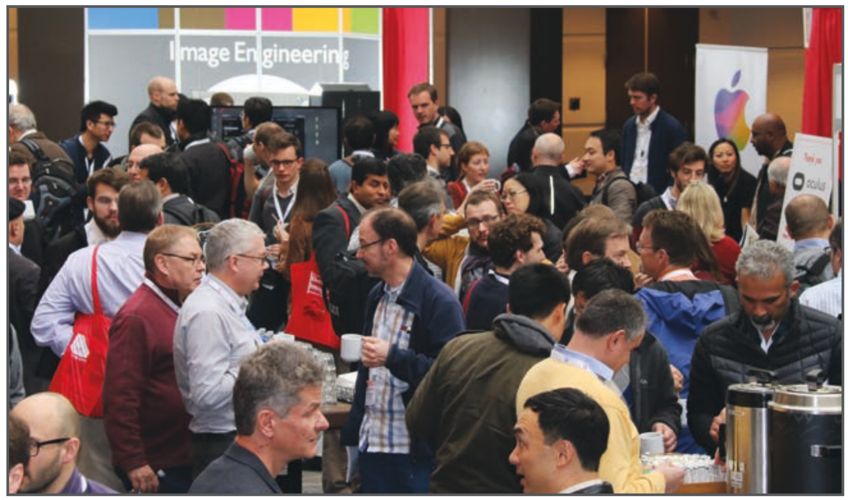

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