



## Editorial

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# Big Data Visualization for the Internet of Things: Opportunities and Challenges with Human Factors

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**Abstract**—Big data and the Internet of Things (IoT) are drawing widespread research interests across multiple areas, along with the systematic analytics supporting the decision-making process. Big data visualization opens up utilization for analyzing the IoT, in which multiple data sources from sensors, services and devices are combined into a single-layered visual interface, improving understanding of the large-scale data collected. This paper focuses on the cross-section in terms of visualization between big data and IoT. In more detail, this work aims to introduce the importance of big data visualization in IoT development, as well as present the opportunities in near future and research challenges to be addressed. The interdisciplinary nature of big data and IoT is emphasized, presented in various visualization applications in multiple aspects regarding direct human factors such as disaster situational awareness, security and user privacy, journalism and social media influence.

**Keywords**—Internet of Things, big data, data visualization, visual analytics, big data analytics.

## I. INTRODUCTION

**B**IG data and the Internet of Things (IoT) have been widely recognized in various fields, from technical areas to applications in business. Both technologies have encouraged a large amount of research interest, opened up vast opportunities for practical applications, at the same time posing remarkable challenges for developers, businesses and decision-makers. On one hand, the IoT introduces the idea of the development of an interconnected world, where physical objects are connected to the Internet, allows users to remotely access the data provided by the operating sensors while collecting different kinds of data [1, 2]. The larger number of connected people, objects, devices, and services requires technologies and tools that can provide effective handling mechanisms in a timely manner. From this notion, IoT draws attention for researchers in numerous fields, including sensor networks management, data communication, temporal and spatial data analysis, and data visualization [3]. On the other hand, big data provide innovation solutions focusing on transforming large scale raw data in a variety of forms: structure, unstructured or semi-structured, into understandable data and metadata format for analytics [4]. The reasoning process using extracted information supports the understanding of

data, thus helps businesses and companies to improve the decision-making process. The use of big data technologies has fundamental importance for data visualization, where technological innovations allow interaction for visualizing the large volume of data generated in real-time [1].

The interdisciplinary nature of big data visualization for the IoT allows boosting analytical power with visual analytics to utilize the full potential of the collected data. One such effort stems at the synergies between IoT and Big data so that both have increased impact [3]. Big data visualization would enable multiple data correlations to be examined and analyzed in real-time. As the technical side in the synergies has been widely recognized [1-4]; in this paper, we discuss big data visualization for the IoT, the opportunities and research challenges, regarding human factors. This work also aims to encourage more useful visualization tools to support visual analytics in analyzing IoT big data.

## II. THE DISCIPLINARY NATURE OF BIG DATA VISUALIZATION AND IOT

The IoT has generated an avalanche of collected data from sensors, devices, and services. Without analytic power and adequate tool for processing and analysis, this

massive amount of data has no value. Big data analytics in IoT requires processing a large amount of data on the fly and storing the data in robust storage technologies [4]. After processing and analyzing the data, as shown in Figure 1, the analytical tools take findings in input to produce the outcome in the forms of visualization such as diagrams, matrices, time-series or spatial graphs, then visual analytics is applied to gain insights from these visual interfaces.

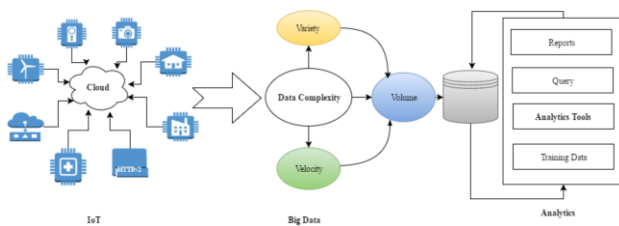


Figure 1. Relationship between IoT and big data analytics [4].

The large scale and high dimension of big data become difficulties in carrying out visualization, in terms of display resources and computing power, hence the obstacle for presentation for the mass audience. Apart from that, one of the prominent factors in IoT analytics is response time. To bring the best out of the enormous collected IoT data, big data visualization must ensure to present data streams in context within a physical environment making data actionable to develop situational awareness [5]. To build a complete picture, the data can come from multiple sources, such as physical monitoring systems [1], surveillance devices [6], or social media [7, 8] to leverage IoT from a social perspective, to develop a real-time visualization platform.

### III. BIG DATA VISUALIZATION FOR IOT: OPPORTUNITIES AND CHALLENGES WITH HUMAN FACTORS

Big data visualization in the context of IoT brings vast opportunities in research areas as well as practical applications, from disaster awareness, security, and privacy concerns, to social media and journalism influence. This section discusses the visualization directly in association with human benefit. Standing alongside with opportunities in the synergies are complex research challenges, which will be described accordingly.

Regarding disaster situational awareness, IoT emergency evaluation and response [9, 10] can be combined with big data visual analytics from extracted mass social media content [7] to obtain a comprehensive visualization for the complete picture of the situation. To this extent of opportunity for incorporation, the computing resources are required to be sufficiently large at processing in real-time, as precision can affect human survivors from the disaster.

Security and privacy are some of the main concerns of end-users in the environment of IoT [1, 2, 7, 8]. To illustrate the relationship between big data and IoT from conversations on social media, the authors in [8] demonstrated users' privacy concerns with an example of Google glass, which can connect to many devices and display personal information. In [11], the Authors presented the negative aspects of the IoT, including privacy risks and accidents relating to self-driving automobile crashes. Although "security" is found to be one of the most popular topics than spans over a long period of time, the reliability from media posts may vary based on its contribution [12]. Social media can be used as a robust platform to promote IoT innovations to a wide audience, who are already familiar with the Internet and technology.

Apart from technical and business areas, recent research demonstrated that journalistic information is also one aspect that is influenced by the IoT [13, 14]. A new paradigm is introduced to the media as ubiquitous journalism [13]. Besides, big data has a socio-material relationship with journalism, about ideation and implementation of computational and mathematical mindsets and skillsets in news work [15]. Data visualization for journalism has been created and developed to witness the measurable facts, trends or process. These visual displays are "less emotionally charged, more concerned with shedding light than heat," with the case of representation of deep political divisions [16]. One example of such visualization is using data extracted from the content of political blog posts to demonstrate the topic evolution, showcasing the emphasizing stories over time [17]. The aggregation of visual analytics power in IoT journalism would deeply enhance the audience's understanding, supporting "ubiquitous journalism" regarding gaining deep insights into technology innovations. However, enabling new facets into data journalism deals with common wisdom as a challenge in making complex visual demonstrations understandable to the mass audience.

### IV. CONCLUSION

This paper provides an overview of big data visualization in IoT regarding human factors, the opportunities, and challenges in conducting visualization at the cross-section between big data and IoT. With human factors, there is more to consider for developers and decision-makers with ideas for bringing IoT innovations into daily life. This also opens many challenges in understandability and privacy concerns, real-time processing for situational emergency awareness. This work initiates some opportunities in supporting IoT visualization to a mass audience while showing the full potential of technology innovations.



**Huyen N. Nguyen** received a B.S. degree in Information Systems from Hanoi University of Science and Technology, Hanoi, Vietnam, in 2018. She is currently a Ph.D. student in Computer Science at Texas Tech University and a member of the interactive Data Visualization Lab (iDVL). She does research in interactive data visualization and visual analytics. Her research on data visualization and visual analytics have been presented in IEEE Visual Analytics Science and Technology and EG/VGTC Conference on Visualization. Her research interest includes visualization methods and applications that support visual analytics and data analysis from large scale data, including quantitative and qualitative data; computer vision, focusing on multi-label classification, and object detection.



**Tommy Dang** is an Assistant Professor of Computer Science at Texas Tech University where he directs the interactive Data Visualization Lab (iDVL). His research on big data visualization and visual analytics has appeared in Computer Graphics Forum and IEEE Transactions on Visualization and Computer Graphics and has been presented at IEEE Information Visualization, IEEE Visual Analytics Science and Technology, EG/VGTC Conference on Visualization, among others. The mainstream of his research is on visual features (or Scagnostics) for analyzing pairwise correlation of multivariate data. Working directly with these measures, his research was able to locate anomalous or interesting subset of variables/sub-series for massive, dynamic, and high dimensional data in scientific and social applications. He also has special interests and skills on 3D modeling, computer animation, and virtual reality. Dr. Dang has previously been a post-doc on a DARPA-funded project on biological network visualization at the Electronic Visualization Lab at the University of Illinois at Chicago which focuses on advanced virtual reality, notably the CAVE2™ hybrid reality environment and the SAGE2™ scalable amplified group environment.

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