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### Visualization Research Lab at HKUST

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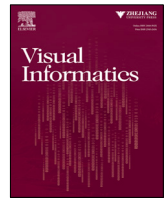
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## Visualization Research Lab at HKUST

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### 1. Overview

HKUST VisLab (<http://vis.cse.ust.hk/>) is one of the leading research labs in the field of data visualization and human–computer interaction worldwide. The lab is dedicated to conducting cutting-edge research on data visualization and human–computer interaction to facilitate data exploration and analytics in various application domains, including E-learning, urban computing, social media and industry 4.0. Starting from its foundation by Prof. Huamin Qu in August 2004, the mission of HKUST VisLab is to build an excellent visualization research center and foster data visualization research and talent cultivation in Asia, as there were very few visualization researchers in Asia around 2004.

HKUST VisLab has become one of the most productive visualization research teams throughout the world. For example, HKUST VisLab has published over 250 high-quality research papers and 62 research papers are published by 2019 in IEEE Transactions on Visualization and Computer Graphics, the top visualization journal, which ranked 2nd throughout the world. The founding director of HKUST VisLab, Prof. Huamin Qu, ranks the third “most influential scholar” in the visualization field over the past ten years according to the survey “AI 2000” by Tsinghua University (<https://www.aminer.cn/ai2000/visualization>). The research of HKUST VisLab has received many awards, including 12 best paper or honorable mention awards, 2009 IBM Faculty Award, 2014 Higher Education Scientific and Technological Progress Award (Second Class) from the Ministry of Education of China, 2015 HKICT Best Innovation (Innovative Technology) Silver Award from the Hong Kong Institution of Engineers, 2015 APICTA Merit Award in E-Learning from the Asia Pacific ICT Alliance, 2016 Distinguished Collaborator Award from Huawei Noah's Ark Lab, 2018 Yelp Dataset Challenge Round 10 Grand Prize Award, and 2019 HKICT Student Innovation Gold Award. HKUST VisLab also works closely with the industry and the technologies developed by the lab have been adopted by Microsoft, IBM, Huawei, Tencent, Bosch, and the like. Multiple research projects have been covered

by the media, including NHK TV, IEEE spectrum, MIT News, Tech in Asia, South China Morning Post, Ming Pao, Wenhui Pao, and so on.

By 2020, HKUST VisLab has grown to a team with over 35 members consisting of a professor, post-doctoral researchers, Ph.D./Mphil students and research assistants/interns, as shown in Fig. 1. The backgrounds of the team members are also diverse and international. They come from Mainland China, Hong Kong, India, Thailand, Japan, Indonesia, France and Spain. To date, 28 Ph.D. and 22 Mphil students have graduated from HKUST VisLab; many of whom continue to work in academia. For example, HKUST VisLab alumni have worked as faculty in universities of both China and abroad, such as Zhejiang University, Tongji University, University of Electronic Science and Technology of China, Shenzhen University and Singapore Management University. Of those, two Ph.D. graduates of HKUST VisLab have been selected by China's 1000 Talented Youth Program, which is one of the most prestigious talent programs for young scientists in China. The alumni of HKUST VisLab have also chosen to conduct research and development work in research labs and high technology companies, such as Microsoft Research Asia, Zhejiang Lab, Bosch Research, Facebook AI lab, IBM Watson Research Center, Webank, Semens and Airbnb. The graduates from HKUST VisLab are pushing the development of visualization research further forward in both Asia and the world.

### 2. Research directions

HKUST VisLab aims to develop advanced visualization and human–computer interaction techniques to boost big data analytics in real-world applications. The recent main research directions of HKUST VisLab can be summarized as follows:

#### 2.1. Visual analytics for online education

Over the past decade, online education has shown significant growth and attracted a remarkable amount of attention from the public. Various online learning platforms have emerged, including both MOOC (massive open online course) platforms (e.g., Coursera and edX) and online question pools (e.g., LeetCode,

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**Fig. 1.** Group photo of HKUST VisLab.

Learnlex and Math Playground). Such learning platforms have accumulated a large volume of raw data such as learners' profiles, video viewing histories, mouse interactions and activities in course forums. We believe a comprehensive study of the data can benefit various stakeholders of online learning, including course designers, instructors, online learners and platform owners. We conducted extensive studies on visual analytics for online education. Specifically, we developed VisMOOC (Shi et al., 2015), one of the earliest comprehensive visual analytic systems worldwide to help education researchers, course designers and instructors to analyze the video clickstreams on online learning platforms (Fig. 2). Then, we explored student activities on learning forums (Fu et al., 2016, 2018), learning sequence analysis (Chen et al., 2015, 2018) and student dropout analysis (Chen et al., 2016) to further guide course instructors and platform owners to gain deeper insights into students' online learning behaviors. Recently, we have also proposed novel data analytics techniques, such as learning path planning (Xia et al., 2019) and student performance prediction (Wei et al.; Li et al., 2020) to achieve personalized online learning for students.

The research on online education by HKUST VisLab has been awarded the HKICT Best Innovation (Innovative Technology) Silver Award and the Asia Pacific ICT Alliance Award in 2015. It was covered by various news agencies, including Ming Pao, Wenwei Po and Ta Kung Pao. Our research outputs have also been integrated into the online learning platform of HKMOOC (<https://learn.hkmooc.hk/>) and the Learnlex platform of TrumpTech Hong Kong (<https://www.learnlex.com/?lang=en>). For more details, please refer to our E-learning project page (<http://vis.cse.ust.hk/groups/e-learning/>).

## 2.2. Industry 4.0

With the advent of Industry 4.0, a vast amount of manufacturing-related data, such as equipment status, product quality and production time cost, is recorded every day by various sensors in smart factories. HKUST VisLab has been working

closely with our industry collaborators (e.g., Huawei Noah's Ark Lab and Bosch Research) to develop novel data-driven approaches to enable efficient data exploration and decision making in smart factories, for example, production fault analysis (Chen et al., 2017) demand forecasting model selection (Sun et al., 2020) and production planning (Sun et al., 2019). Part of the research in this direction has been employed by Huawei and Bosch in their real production. Our work on reliable production planning (Fig. 3) is also covered by the official WeChat account of Huawei Noah's Ark Lab (<https://mp.weixin.qq.com/s/U-WfClqRPhsQw1ou2sRchQ>).

## 2.3. Social media

Social media analysis is one of the major research directions of HKUST VisLab that can be traced back as far as 2010. The Internet and social media have revolutionized the ways human beings are living and tons of information has been accumulated. How to explore and analyze the data collected by social media has become a big challenge due to its size and complexity. HKUST VisLab has developed a series of novel visualization techniques to enable easy and convenient data exploration of social media, for example, context-preserving dynamic word cloud (Cui et al., 2010), topic evolution and competition (Cui et al., 2011; Xu et al., 2013), opinion extraction (Wu et al., 2010) and information diffusion visualization (Cao et al., 2012). Fig. 4 shows an example of our visualization techniques that we proposed for presenting and exploring topic competition. These advanced visualization techniques for social media data analysis have been well recognized by both academia and the industry. Our research on visualizing user searching log data (Shi et al., 2014) has been awarded the best paper award in IEEE VIS 2014. Our recent work WeSeer (Li et al., 2018a), which targets tracking and exploring information diffusion on WeChat, has been employed by Tencent as an internal tool to help them tackle fake news on WeChat (<https://www.techinasia.com/weseer-smarter-censorship-china>).

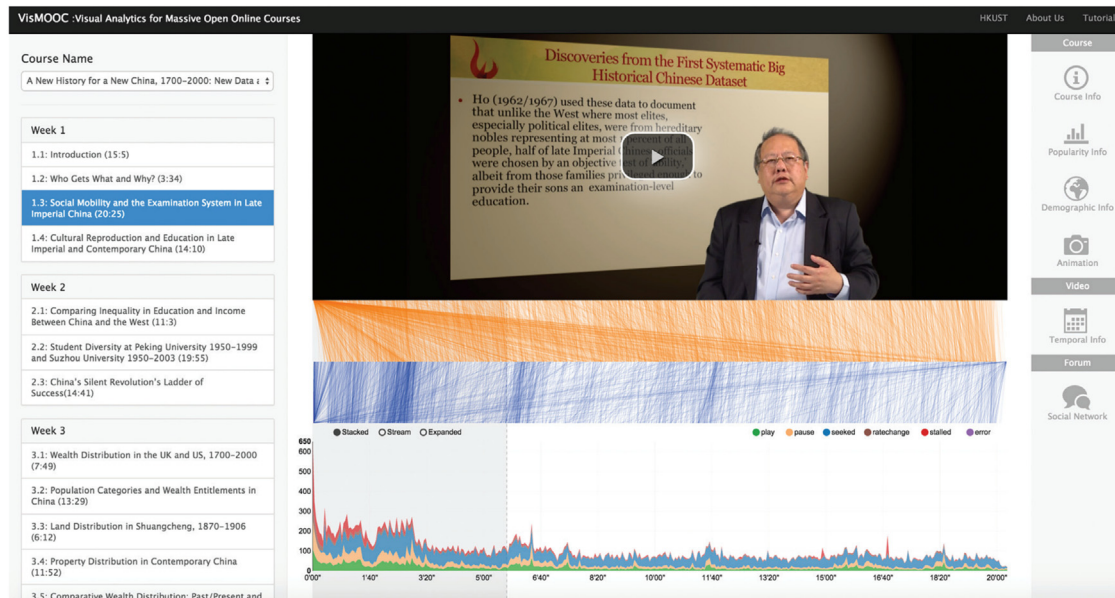


Fig. 2. The user interface of VisMOOC, a visual analytics system to facilitate the analysis of student clickstream data from online learning platforms.

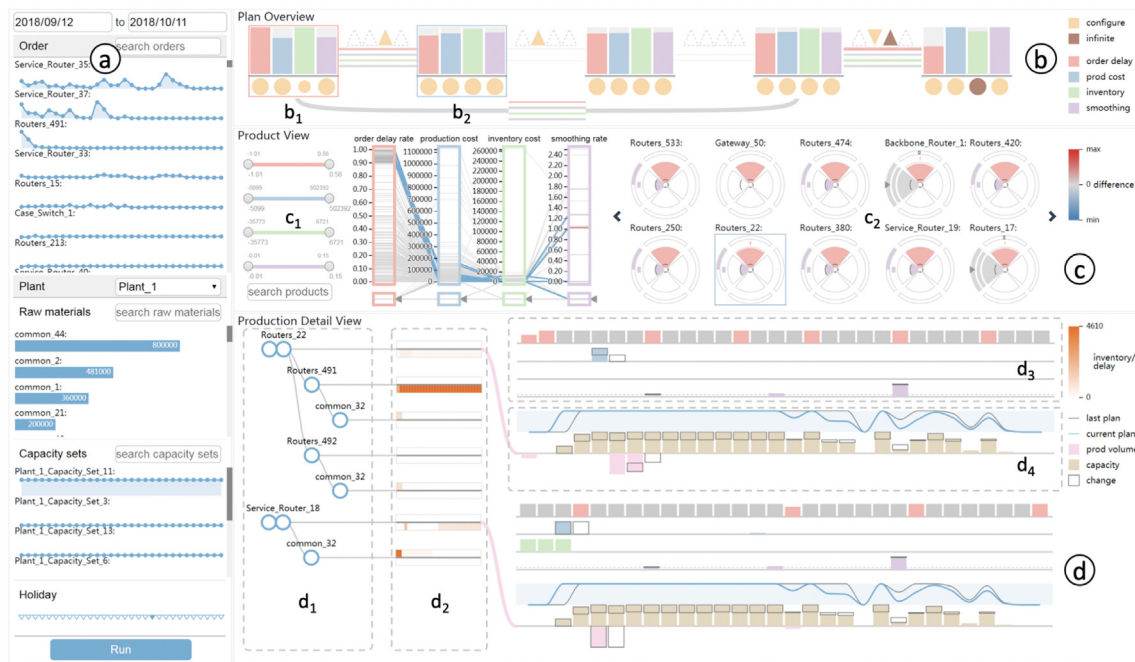


Fig. 3. The visual analytics system, PlanningVis, developed by HKUST VisLab for production planning in smart factories.

#### 2.4. Speech and education video analysis

Apart from online education, HKUST VisLab also investigated how visualization techniques can enhance traditional education and professional training. Specifically, HKUST VisLab has proposed combining artificial intelligence (AI) techniques with visualization approaches to analyze public speaking videos and classroom videos, and to facilitate professional speaking training and classroom education. We developed EmotionCues (Zeng et al., 2020) to enable automated student emotion extraction from classroom videos and interactive multi-level visual summarization of student emotions, as shown in Fig. 5. It can help teachers easily gain insights into student engagement in class and further improve their teaching, instead of checking the original

videos. By applying our approach to Kindergarten classroom videos, parents can also easily see whether their children are happy in kindergarten or bullied by others. Our research has received lots of attention from both academia and the industry, and was covered by NHK TV and IEEE Spectrum (<https://spectrum.ieee.org/the-human-os/biomedical/devices/ai-tracks-emotions-in-the-classroom>).

By working closely with our industry collaborator, Own The Room Asia Limited, we also studied the emotion coherence across facial, text and audio modalities in good presentation videos (Yuan et al., 2019; Zeng et al., 2019) and further built an interactive evidence-based training system for voice modulation skills in public speaking (Wang et al., 2020). The research outputs have been integrated into the speech training system of Own The Room, i.e., Lifehikes (<https://www.lifehikes.com/>).



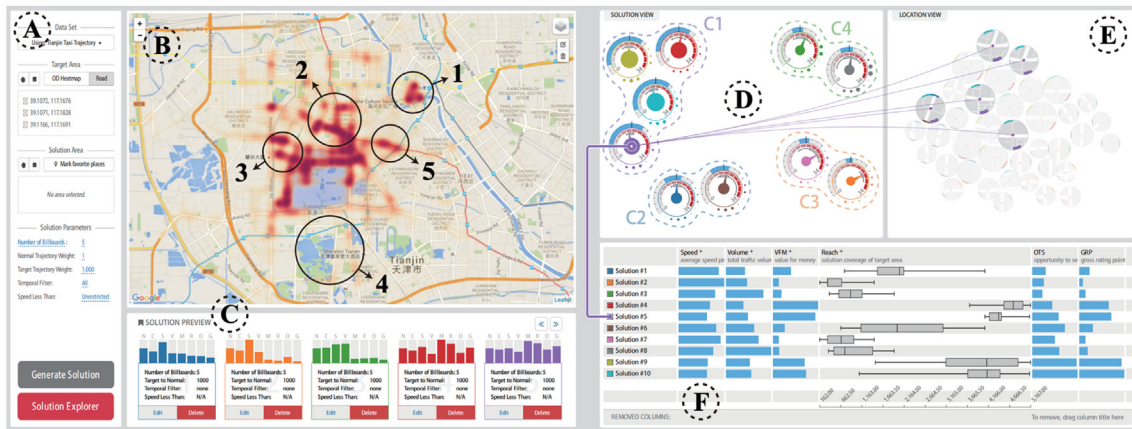


Fig. 6. The user interface of SmartAdP (Liu et al., 2016).



Fig. 7. Our “Pulse of HKUST” system has been deployed and displayed in the Engineering School Commons in HKUST.

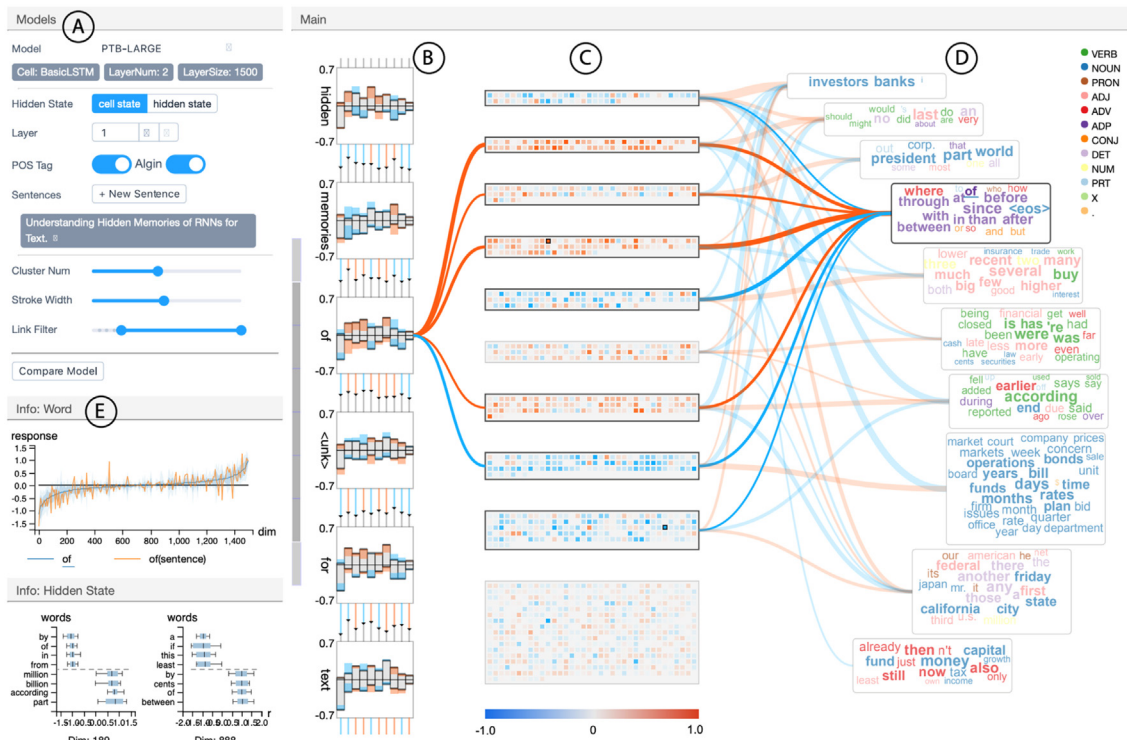
## 2.6. Explainable machine learning

The past few years have witnessed increasing applications of machine learning models in various domains. However, the complexity of machine learning algorithms, especially the deep learning models, often makes them difficult for general users to understand, hindering their usage in critical domains such as finance, security, and healthcare. HKUST VisLab has proposed human-centered approaches to make AI explainable, interactive, and trustworthy (<http://vis.cse.ust.hk/groups/xai-vis/>). We developed novel visual analytics techniques to enhance the interpretability of both traditional machine learning models (e.g., random forests (Zhao et al., 2018) and network embeddings (Li et al., 2018b)) and advanced deep neural networks (e.g., CNNs (Liu et al., 2018a) and RNNs (Ming et al., 2017)). For instance, we proposed a visual analytics method to explain the function of individual hidden state units of RNN models based on their expected response to input texts (Ming et al., 2017), which can help model users

understand and compare RNN models for NLP tasks, as shown in Fig. 8.

In addition, beyond just visualizing the machine learning models, we also propose an interpretable and steerable deep sequence model that intrinsically owns natural explanations derived from a few prototypes (i.e., exemplar cases) (Ming et al., 2019b,a). Furthermore, given the increasing popularity of using automated machine learning (AutoML) to search good models and its huge search space, we designed ATMSeer (Wang et al., 2019b), an interactive visual analytics tool to help users efficiently refine the search space of AutoML and explore the model results. As one of the earliest visual analytics tools for AutoML, ATMSeer was covered by MIT news (<https://news.mit.edu/2019/atmseer-machine-learning-black-box-0531>).

Besides the above five major research directions, HKUST VisLab has also conducted a series of preliminary research on immersive analytics (Chen et al., 2019a), visualization-based financial technology (Yue et al., 2018, 2019), graph visualization (Wu et al.,



**Fig. 8.** RNNVis is a visual analytics method developed by HKUST VisLab to help non-expert users understand the hidden memories of Recurrent Neural Networks (RNNs).

2015) and AI-powered visualizations (Chen et al., 2019b; Wang et al., 2019a). For more details on the research above, please refer to the HKUST VisLab website: <http://vis.cse.ust.hk/>.

### 3. Research culture

As reported above, HKUST VisLab has conducted much exciting research in the field of data visualization and human–computer interaction, which, we believe, has also highly benefited from its unique research culture.

**Open and free research environment.** In the same vein as Albert Einstein, “love is a better teacher than duty”. HKUST VisLab tries the best to respect the research interests of every student and build an open and free research environment for the whole team. When a new member joins the team, Prof. Huamin Qu will hold a meeting to discuss the possible research directions of his/her interests. During the early stages of the paper submission period, HKUST VisLab will give every student who has a paper submission plan to present their overall idea in the group seminars, and other students can choose to join a paper submission team of their interest if they wish.

**Encourage broad collaboration.** HKUST VisLab always encourages the students to collaborate with researchers within or outside the group, especially senior researchers in the visualization field. By doing this, students can learn from their collaborators, form better teamwork skills and build their own research collaboration network, which are all critical for their future research careers.

**Record and trace everything.** HKUST VisLab has its own internal bbs since its foundation in 2004. All the students are required to record all of their research-related stuff on the bbs. For example, every Ph.D. student is asked to write their weekly reading notes on the bbs. The group seminars, presentations, project research progress, ideas, paper submission reflection articles, and the like are all written down on the bbs. With such rich records,

the current team members can easily share their findings and ideas with each other, check the potential reasons for their paper submission failures or project troubles by viewing their records, and learn from other team members by checking their growth traces on the BBS.

**Work hard and play hard.** Life in HKUST VisLab is exciting and colorful. During work time, all team members will work extremely hard on various interesting and exciting research and development projects. There will be meetings, discussions, programming and presentations by following an almost “24 h a day and 7 days a week” agenda. Meanwhile, HKUST VisLab also gives the team members very flexible schedules to allow them to relax and enjoy life. For example, HKUST VisLab members will have long holidays after a VIS paper submission, in the summer and around Chinese New Year. Many colorful activities are often organized, such as hiking, eating and traveling to different countries.

### 4. International collaborations

HKUST VisLab has built extensive international collaborations with the universities, research labs and within the industry in Hong Kong, mainland China and other overseas countries/regions. Such kind of collaborations are achieved in various ways, including a postgraduate student visiting program, visiting scholars, collaborative funding and remote collaborations. For industry, we have collaborated with Microsoft Research Asia, Tencent, Huawei, Bosch Research, IBM Watson, NetEase, FX Palo Alto Laboratory, Airbnb, Visa Research, Adobe Research, Rice Quant, Trumplech Hong Kong, and Own The Room Asia Limited, and the like. For universities, we have been fortunate to have worked with researchers from Oxford, MIT, INRIA, Nanyang Technological University, Tsinghua University, Hong Kong University, University of Edinburgh, University of Arizona, Swansea University, Zhejiang University, Tongji University, Chinese Academy of Sciences and many more.

## 5. Visions for the future

As mentioned above, the mission of HKUST VisLab has always been to build an excellent visualization research center and foster the data visualization research and talent cultivation in Asia, which still holds today. After 16 years' development, we are glad to see that visualization research has grown significantly in Asia. In the future, HKUST VisLab will continue to be dedicated to cutting edge visualization research and visualization talent cultivation. We are eager to further push forward the research development of the whole visualization field and expand its impact on the industry as well as the daily lives of humankind.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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