EG2013 Tutorial on Video Visualization

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Abstract

Video data, generated by the entertainment industry, security and traffic cameras, video conferencing systems, video emails, and so on, is particularly time-consuming to process by human beings. The field of visualization has provided this challenging problem with a collection of techniques that transform videos to different visual forms in order to reduce the time required to watch the video. In this tutorial, we will introduce the concept of video visualization, and several elementary techniques for processing and rendering a video into a compact visual representation. We will describe a family of visual representations, a set of insight obtained from empirical studies, and a collection of applications.

Keywords: *Video visualization, visual analytics of videos, video abstraction, video summarization, taxonomy, visual designs, applications in sports sciences, biomedical applications, computer vision, and security industry.*

1. Introduction and Motivation

Video visualization is concerned with the creation of a new visual representation from an input video to reveal important features and events in the video. It typically extracts meaningful information from a video and conveys the extracted information to users in abstract or summary visual representations, which are typically more compact than the input video itself. Video visualization is not intended to provide fully automatic solutions to the problem of making decisions about the contents of a video. Instead, it aims at offering a tool to assist users in their intelligent reasoning while removing the burden of viewing videos. In particular, it can be used to fill in many gaps in practice where automated computer vision is yet to provide usable solutions. This aim justifies deviation from the creation of realistic imagery, and allows simplifications and embellishments, to improve the understanding of the input video.

Video data is inherently a form of volumetric data, and it also exhibits some flow-like features, such as motion flows. There have been many tutorials on the advances in volume visualization since 1980s, and those in flow visualization since 1990s. Despite that video data is more abundant and ubiquitous than medical imaging data, or flow simulation data, there has not been any educational programmes on video visualization. This is rather incompatible with the fact that the rapid advance of digital recording and creation technologies has resulted in an explosion of video data. As visual search through videos is time-consuming, often tedious, and mostly involves watching videos repeatedly, there is a real urgency to engage more researchers in developing new techniques for visualizing videos.

The development of video visualization started in early 2000s, which saw the emergence of a collection of novel visual designs that allow viewers to gain an insight about a video rapidly, usually without the need for watching the video. Recently, visual analytics techniques have been applied to the process of video analysis, ranging from interactive exploration to interactive construction of classifiers. The use of video visualization has also been extended from security and entertainment applications to sports and biomedical applications.

This tutorial has not been previously taught in any conference. Several presenters were co?authors of a Eurographics 2011 STAR entitled "*A survey on video?based graphics*

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and video visualization" [BCD*12]. This tutorial will complement this survey by providing the audience with a gentle introduction of the technical pipelines, design principles and fundamental processing and rendering techniques, while presenting a set of core techniques and a range of practical applications that were not detailed in the survey. We prepared the presentation slides based on a collection of papers listed in the Further Reading section. The DOI links for these papers can be found at:

http://www.oerc.ox.ac.uk/
personal-pages/min/ftp/eg2013vv/videovis/

In addition, you can also find a set of slides in the Eurographics 2013 USB Proceedings.

2. Schedule

Session 1

1. Tutorial Introduction [10 min]
2. A "Hello" Pipeline and Use Case
   [15 min (plus 5 min Q&A)]
3. The Taxonomy of Video Visualization [25 min (+5)]
4. Visual designs for video visualization [25 min (+5)]

Coffee/Tea Break

Session 2

5. Visual analytics of Videos [15 min (+5)]
6. Empirical Studies and User Evaluation [25 min (+5)]
7. Applications [25 min (+5)]
8. Summary and overall Q&A [5 min (+5)]

3. Target Audience and Prerequisites

This tutorial is designed for the general audience of Eurographics conferences, and it is especially suitable for new PhD students who are looking for new and exciting topic areas to develop their PhD projects as well as experienced researchers who wish to broaden their research horizon. The tutorial requires a minimal level of prerequisites. Many fundamental topics, such as visualization designs, basic video processing techniques, and evaluation methods, will be covered in the tutorial. The tutorial does not require audience to have the experience of any specific programming language or graphics API, though the knowledge about programming and computer graphics will be helpful.

4. Organizers and Presenters

Min Chen, Co-organizer

Professor Min Chen received his Ph.D. degree from University of Wales in 1991. He is currently a professor of scientific visualization at Oxford University and a fellow of Pembroke College. Before joining Oxford, he held research and faculty positions at Swansea University (i.e., research officer from 1987, lecturer from 1990, senior lecturer from 1998 and professor from 2001). His research interests include visualization, computer graphics, human-computer interaction and some aspects of computer vision. He has co-authored about 140 publications, including his pioneering works on video visualization. His services to the research community include papers co-chair of IEEE Visualization 2007 and 2008, co-chair of Volume Graphics 1999 and 2006, papers co-chair of Eurographics 2011, associate editor-in-chief of IEEE Transactions on Visualization and Computer Graphics, associate editor of Elsevier Computers & Graphics, member of a number of program committees, and co-director of Wales Research Institute of Visual Computing. He is a fellow of British Computer Society, European Computer Graphics Association, and Learned Society of Wales.

Daniel Weiskopf, Co-organizer

Professor Daniel Weiskopf received the Diplom (MSc) degree in physics and the Dr. rer. nat. (PhD) degree in physics, both from the University of Tübingen, Germany, and he received the Habilitation degree in computer science at the University of Stuttgart, Germany. From 2005 to 2007, Dr. Weiskopf was an assistant professor of computing science at Simon Fraser University, Canada. Since 2007, he has been a professor of computer science at the Visualization Research Center, University of Stuttgart (VISUS) and at the Visualization and Interactive Systems Institute (VIS), University of Stuttgart. His research interests include visualization, visual analytics, GPU methods, real-time computer graphics, perception-oriented computer graphics, and special and general relativity. Dr. Weiskopf co-authored a book on real-time volume graphics and authored a book on GPU-based interactive visualization techniques. He is regularly teaching courses and seminars on computer graphics, visualization, visual analytics, geometric modeling, and computer animation. He was the co-organizer of the SIGGRAPH 2001 Course on "Visualizing Relativity" and the organizer of the IEEE Visualization 2003 Tutorial on "Interactive Visualization of Volumetric Data on Consumer PC Hardware" and the IEEE Visualization 2004 Tutorial on "Interactive, Texture-Based Flow Visualization". In addition, he participated in the Eurographics 2002 Tutorial on "Programmable Graphics Hardware for Interactive Visualization", the Eurographics 2003 Tutorial on "Programming Graphics Hardware", the IEEE Visualization 2006 Tutorial on "Texture and Feature-Based Flow Visualization", and the IEEE VisWeek2009 Tutorial on "Visualization of Time-Varying Vector Fields". He has extensively co-authored papers on video visualization and visual analytics, including a Eurographics / Computer Graphics Forum State-of-the-Art Report on "Video-Based Graphics and Video Visualization". He chairs the Eurographics working group on Parallel Graphics. He is co-editor of the Visualization Corner of Computing in Science & Engineering, associate editor of IEEE Transactions on Visual-

ization and Computer Graphics, and member of the editorial board of The Visual Computer.

Rita Borgo

Dr. Rita Borgo received her BSc and MSc (Laurea with commendation) from the University of Bologna in 2000 and PhD in Computer Science in 2004 from the University of Pisa in collaboration with the Visual Computing Lab. at the Italian National Research Council in Pisa. Since 2011 she has been a Lecturer in the Department of Computer Science, Swansea University, United Kingdom. Her research interests include video visualization, time series visualization, human computer interaction, perceptual cognition, computational geometry, hierarchical meshes and progressive algorithms. Her main current research focus is on video visualization and 3D image analysis and synthesis. Her contributions to the field have touched upon both aspects of video summarization and user-centred video visualization. She is a member of BCS Women in Computer Science and IEEE.

Markus Höferlin

Markus Höferlin received the MSc (Diplom) degree in Computer Science from the University of Stuttgart, Germany, in 2008. He is currently working towards the PhD degree at the Visualization Research Center, University of Stuttgart (VISUS). His research interests include visual analytics of video data and video visualization. His developed visual analytics approach received the "Outstanding Video Analysis Tool" award for the video mini challenge of the IEEE VAST Challenge 2009. He has co-authored various papers on visual analytics for video data, and video visualization, including a Eurographics / Computer Graphics Forum State-of-the-Art Report on "Video-Based Graphics and Video Visualization".

Kuno Kurzhals

Kuno Kurzhals received the MSc (Diplom) degree in Computer Science from the University of Stuttgart, Germany, in 2012. Currently, he is a PhD candidate at the Visualization Research Center, University of Stuttgart (VISUS). His research interests are in video visualization techniques and evaluation methods with focus on user studies. The research of his MSc (Diplom) thesis covers the topic of his tutorial presentation; a part of this research (evaluation of fast-forward video visualization) was published in IEEE Transactions on Visualization and Computer Graphics in 2012.

Phil Legg

Dr. Phil Legg is a research assistant at Swansea University. He completed his PhD in 2010 at Cardiff University studying medical image processing, and since then he has specialized primarily in sports video visualization. Due to the overwhelming reliance on video recordings in sport, video visualization can play a crucial role for efficiently reviewing data, and can also serve as an effective tool for identify previously unnoticed characteristics in the data. Through the combination of video processing and data visualization techniques, his work enables athletes and coaching analysts to quickly analyze, interpret and understand match and training performance data. He has worked in collaboration with internationally recognized sports institutes in football, snooker and rugby, including the Welsh Rugby Union who incorporated his MatchPad visualization tool as part of their performance analysis at the Rugby World Cup 2011 and 6 Nations 2012.

Simon Walton

Dr. Simon Walton completed his PhD in 2007 at Swansea University, focusing on the deformation of discretely sampled object representations using GPUs. Since then, he has worked as a researcher in a number of projects on industrial data visualization, video visualization and mobile human-computer interaction. He now works as a research associate at the Oxford e-Research Centre, Oxford University. His recent interests are focused on Video Visualization techniques with a focus on the interesting perceptual challenges of combining many different layers of information in the same visualization.

References

[BBS*08] BOTCHEN R. P., BACHTHALER S., SCHICK F., CHEN M., MORI G., WEISKOPF D., ERTL T.: Action-based multi-field video visualization. *IEEE Transactions on Visualization and Computer Graphics 14*, 4 (2008), 885–899.

[BCD*12] BORGO R., CHEN M., DAUBNEY B., GRUNDY E., JÄNICKE H., HEIDEMANN G., HÖFERLIN B., HÖFERLIN M., WEISKOPF D., XIE X.: State of the art report on video-based graphics and video visualization. *Computer Graphics Forum 31*, 8 (2012), 2450–2477. 2

[CBH*06] CHEN M., BOTCHEN R. P., HASHIM R. R., WEISKOPF D., ERTL T., THORNTON I. M.: Visual signatures in video visualization. *IEEE Transactions on Visualization and Computer Graphics 12*, 5 (2006), 1093–1100.

[CRS06] CHEN M., ROBINSON J., SILVER D.: Illuminating the path of video visualization in the shadow of video processing. In *invited survey in Proc. International Symposium of Multimedia* (2006), pp. 219–226.

[DC03] DANIEL G. W., CHEN M.: Video visualization. In *Proc. IEEE Visualization 2003* (2003), pp. 409–416.

[HGB*10] HÖFERLIN M., GRUNDY E., BORGO R., WEISKOPF D., CHEN M., GRIFFITHS I. W., GRIFFITHS W.: Video visualization for snooker skill training. *Computer Graphics Forum 29*, 3 (2010), 1053–1062.

[HHWH10] HÖFERLIN B., HÖFERLIN M., WEISKOPF D., HEIDEMANN G.: Information-based adaptive fast?forward for visual surveillance. *Springer Multimedia Tools and Applications 55*, 1 (2010), 127–150.

[HHWH11] HÖFERLIN M., HÖFERLIN B., WEISKOPF D., HEIDEMANN G.: Uncertainty-aware video visual analytics of tracked moving objects. *Journal of Spatial Information Science 2* (2011), 87–117.

[HHWH13] HÖFERLIN M., HÖFERLIN B., WEISKOPF D., HEIDEMANN G.: Interactive schematic summaries for faceted exploration of surveillance video. *to appear in IEEE Transactions on Multimedia* (2013).

[HKH*12] HÖFERLIN M., KURZHALS K., HÖFERLIN B., HEIDEMANN G., WEISKOPF D.: Evaluation of fast-forward video visualization. *IEEE Transactions on Visualization and Computer Graphics 18*, 12 (2012), 2095–2103.

[HNH*12] HÖFERLIN B., NETZEL R., HÖFERLIN M., WEISKOPF D., HEIDEMANN G.: Inter-active learning of ad-hoc classifiers for video visual analytics. In *Proc. IEEE VAST* (2012).

[JBMC10] JÄNICKE H., BORGO R., MASON J. S. D., CHEN M.: SoundRiver: Semantically-rich sound illustration. *Computer Graphics Forum 29*, 2 (2010), 357–366.

[LCP*12] LEGG P., CHUNG D., PARRY M., JONES M., LONG R., GRIFFITHS I., CHEN M.: MatchPad: Interactive glyph-based visualization for real-time sports performance analysis. *Computer Graphics Forum 31*, 3 (2012), 1255–1264.

[PLC*11] PARRY M. L., LEGG P. A., CHUNG D. H. S., GRIFFITHS I. W., CHEN M.: Hierarchical event selection for video storyboards with a case study on snooker video visualization. *IEEE Transactions on Visualization and Computer Graphics 17*, 12 (2011), 1747–1756.

[TFA*11] TAM G. K. L., FANG H., AUBREY A. J., GRANT P. W., ROSIN P. L., MARSHALL D., CHEN M.: Visualization of time-series data in parameter space for understanding facial dynamics. *Computer Graphics Forum 30*, 3 (2011), 901–910.