How to Read a Visualization Research Paper: Extracting the Essentials

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Abstract

PhD students or researchers starting a new research project or initiating work in an unfamiliar research direction often undertake a scientific literature search in order to inform themselves with respect to a chosen topic. This start-up phase involves wading through and reading scores, if not hundreds, of research papers that have already been published in the area of interest. Reading a large quantity of scientific papers and capturing the essential information from them is a very challenging task. Furthermore, this difficulty only increases with the passage of time as the complexity of literature increases as well as the quantity of publications.
This paper aims to instruct a starting PhD candidate or researcher on how to read a visualization research paper. By "read" we mean extracting the essential, most important information from a (previously) published scientific conference or journal paper. During the course of a PhD, the candidate will read many research papers containing a vast amount of information. However, it is not possible to remember all of the details presented, nor is it necessary. Here we identify and describe the essential knowledge that is best extracted and summarized when reading a visualization paper.

1. Introduction and Motivation

When undertaking an unfamiliar research direction, the researcher, possibly a PhD candidate is required undertake a literature search. A literature search is performed to discover what work has already been carried out in a given field (solved problems) and likewise what work has not yet been undertaken, i.e., unsolved problems.

However, in visualization and computer graphics, reading a refereed conference or journal paper can be very challenging due to the high level of specialization, complexity, and detail contained in an individual paper. A scientific paper often presents a detailed mathematical framework accompanied by algorithms and data structures to carry them out and are usually written by (or with the aid of) experts in the field with many years of experience. This complexity does not come as a great surprise since a single paper is often the result of multiple (combined) man-years of work.

Furthermore, a new PhD candidate or researcher starting in a new direction must wade through scores, if not hundreds, of such research papers. This is a very challenging and even daunting task. Keeping up with the explosion of literature was identified by Jim Blinn as a top future research challenge [Bli99, LK07]. However, gaining a complete understanding of every published research paper including all of its details is neither possible nor necessary.

Here we describe an educational approach to extracting the essential information when reading a visualization (or computer graphics) paper. The aim is to describe how to read a visualization research paper in order perform a literature review, e.g., to write a state-of-the-art (STAR) report. A STAR report, a.k.a. a survey paper, is a very helpful way to get an overview of previously published work in a sub-field of visualization and computer graphics.

Here we build on both our experience of writing surveys [LHD*04, LK07, LHZP07, MLP*09, MLP*10, PVH*02, PL09, PVH*03] and in the classroom. This guide

submitted to *CGA* (5/2010).

Overview

- Introduction and Motivation
- Related Work
- Concept versus Implementation
  - Example(s)
- Extracting the Essentials of a Visualization Resear
  Paper
  - Concept, Implementation, Related Work, Data Characteristics, (Vis techniques, Application Domain)
- Sample Classifications
- Breadth versus Depth
- Conclusions


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Introduction and Motivation

A new research project often starts with literature review

- **Goal**: determine solved (and unsolved) problems
- A single paper can be very complex, e.g., detailed mathematical framework, complex algorithms and data structures
- Each paper is generally result of multiple-man years written by experts with several years experience
- A *very **large volume*** of previous literature exists
- Keeping up with literature explosion identified as (one of) top future challenges in field by Jim Blinn [Blinn '99, Laramee and Kosara '07]
- How can we navigate through this mass of complexity?

Extracting the Essentials

- Not all details are essential (nor possible) when obtaining an overview of the literature
- We describe an approach to extracting essentials of a visualization research paper.
- **Goal:** for purposes of writing a survey paper, a.k.a. state-of-the-art (STAR) report
- A survey paper is a good way to obtain an overview of literature, i.e., find solved and unsolved problems
- Based on experience in writing surveys [Laramee et al, '04, '07, McLoughlin et al, '09, '10, Peng and Laramee, '09, Post et al., '02, '03]
- And classroom experience

Related Work

Much previous work related to writing surveys directly.

- Taylor '09 writing a survey on health sciences, Lie '09 on writing a psychology survey
- This work is more specific: focus is on one research paper and how it is read
- Smith '90, Lee '95 describe how to read a research paper for reviewing purposes
- Globus and Raible '94: how to cheat when writing a visualization research paper
- Munzner '08: on preventing an information visualization paper rejection

Concept versus Implementation: Dictionary

Concept

“1. a general notion or idea; conception.

2. an idea of something formed by mentally combining all its characteristics or particulars; a construct.

3. a directly conceived or intuited object of thought.'” -dictionary.com

Implementation:

“1. the act of accomplishing some aim or executing some order;

2. the act of implementing (providing a practical means for accomplishing

something); carrying into effect” -dictionary.com

Concept versus Implementation

Concept: an idea or thought.

- A concept is abstract: not something with mass that can weighed on a scale (if that helps).

Implementation: an actualization, or realization of a concept (or idea).

- An implementation is a concept that has been brought into reality.

A concept usually starts out as idea in someone's mind.

- A concept is then often written down on paper perhaps as a hypothesis or a specification. (Better to write it down than simply communicate it verbally.)
- Lastly a concept is implemented.

Concept versus Implementation: Generic Example

Generic Example:

Generic Concept: writing utensil

- A writing utensil is a concept.
- A tool that can be used to communicate with others using symbols drawn by a person (or animal).

Implementation: a pencil

- A pencil is a (type of) writing utensil, or more specifically, it is the implementation of a writing utensil.
- With a pencil, graphite is used to write down on a piece of paper.

Implementation: Generic Example

- Furthermore, there are many different implementations of a writing utensil, e.g., pens, markers, palm pilots, etc.
- Essentially an unlimited variety of different implementations of a writing utensil. How many different pens and pencils you have seen in your lifetime?
- **Important:** for a given concept, there may be many different implementations.
- An important distinction when reading or writing a research paper, as well as in most other areas of life that require critical thinking.

Extracting Essentials of a Visualization Research Paper

Essentials:

- **Concept:** What, conceptually, are authors trying to achieve?
  - What is goal of work?
  - What is ***contribution*** of paper? (What's new here?)
- **Implementation:** How is concept realized?
  - How do authors support their hypothesis?
  - How do they implement concept?
- **Related Work:** What previous work does this paper build upon? Almost all research papers build heavily upon one or two previous papers. What are these?
- **Data Characteristics:** What are characteristics of data analyzed and visualized in paper?
  - What is spatial dimensionality? (2D, surfaces, or 3D)
  - What is temporal dimensionality? (static or time-dependent)
  - What is resolution and size of data set?
  - Is data multi-resolution or adaptive resolution?
  - Are data samples given on a structured or unstructured grid?
  - Is it abstract, scalar, vector, or tensor data?
  - Is it multi-variate data?

Extracting Essentials of a Visualization Research Paper: Example 1

Title: Fast and Resolution Independent Line Integral Convolution by D. Stalling and H.-C. Hege '95

1. **Concept:** This paper presents a faster version of Line Integral Convolution (LIC) algorithm. It brings original LIC algorithm towards interactive frame rates.

2. **Implementation:** They achieve this by reducing number of redundant streamline computations. They also use an improved streamline integrator with adaptive step-size control.

3. **Related Work:** This work builds upon and improves the original LIC Algorithm of Cabral and Leedom '93.

4. **Data Characteristics:**
   - spatial dimensionality: 2D
   - temporal dimensionality: steady (static)
   - resolution: uniform
   - grid structure: regular, Cartesian
   - data type: vector

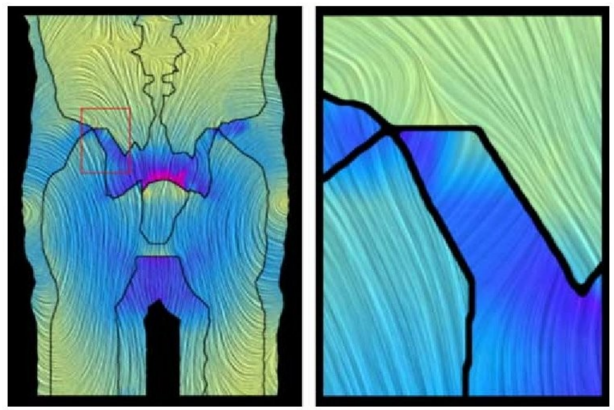

Figure 1: LIC image of a vector field (electrical field) containing discontinuities. Field strength $|v|$ is indicated by color.

Other Candidate Essentials

Essential attributes of a visualization paper are also attributes that can be used to categorize them.

- Above is not a comprehensive list of characteristics that can be used for classification.

Some other characteristics that could be used and summarized include:

5. **Visualization Techniques:** What basic visualization techniques are used? For example, volume rendering, ray tracing, geometric or texture-based flow visualization, information visualization techniques, parallel coordinates or treemaps.

6. **Application Domain:** What application domain are visualization techniques being applied to? For example, physics, earth sciences, astronomy, chemistry, biology, etc.

Extracting Essentials of a Visualization Research Paper: Example 2

Title: Marching Cubes: A High Resolution 3D Surface Construction Algorithm [W.E.Lorensen and H.E. Cline '87]

1. **Concept:** This paper describes a novel algorithm for construction of isosurfaces. Isosurfaces produced from algorithm stem from maintaining the inter-slice connectivity of original data.

2. **Implementation:** basic implementation consists of following steps: (1) examine a cube, (2) classify each cube vertex as inside or outside the isosurface, (3) build an index into case table of all possible surface topologies through cube, (4) get an edge list from case table, (5) interpolate to find edge locations, (6) compute gradients, and (7) go to next next cell.

3. **Related Work:** Marching cubes algorithm builds on and improves algorithms presented by Chen et al. [Chen '85] and Herman and Udupa [Herman '83].

4. **Data Characteristics:**
   - spatial dimensionality: 3D
   - temporal dimensionality: steady (static)
   - resolution: uniform
   - grid structure: uniform resolution, regular
   - data type: scalar

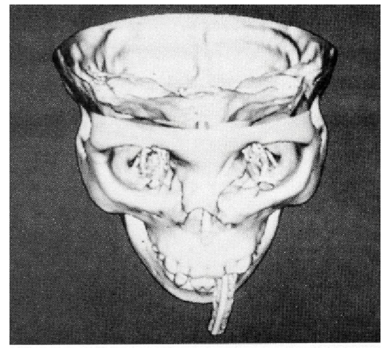

Figure 8. Bone Surface.

5. **Visualization Techniques:** volume visualization, isosurface rendering

6. **Application Domain:** visualization of medical (MR) data, Single-Photon Emission Computed Tomography (SPECT) data

		Topology Extraction			Topology Simplification	
Scalar Data		Static	Dynamic		Static	Dynamic
	2D	[19]		2D	[5] [6]	
	2.5D	[44] [26] [45]	[7]	2.5D	[13] [16] [61]	
	3D	[40] [62]		3D	[17]	
Vector Field Data		**Steady**	**Unsteady**		Steady	Unsteady
	2D	[55] [56] [87] [73]	[21] [53] [80] [89] [83] [68] [71] [72]	2D	[8] [10] [9] [38] [77] [82] [76] [64] [67] [66]	
	2.5D	[22] [30] [32] [75] [84]		2.5D		
	3D	$[37]_v$ $[27]_v$ $[59]_v$ $[29]_v$ $[31]_v$ $[51]_v$ $[18]_v$ $[46]_v$ $[28]_v$ $[41]_v$ $[58]_v$ $[54]_v$ [23] [39] [88] [43] [42] [70] [41] [14] [74] [60] [86] [33]	$[2]_v$ $[3]_v$ $[49]_v$ $[4]_v$ [15]	3D	[85]	
Tensor Field Data		Steady	Unsteady		Steady	Unsteady
	2D	[91]	[11] [79]	2D	[78] [82] [81]	
	2.5D			2.5D		
	3D	[24] [90] [92] [93] [25]		3D		

Table 1.1. An overview and classification of topology-based methods in visualization. Research is divided up into topology extraction and topology simplification literature. Methodology is further classified according to scalar vs. vector vs. tensor field data analysis. Finally, a sub-classification is made based on data dimensionality, both spatial and temporal. References are listed in chronological order within each spatio-temporal dimensionality. In Section 1.2. we focus on the research with **bold** emphasis–topological analysis of vector field data. References subscripted with a $_v$ denote research related to vortex core extraction.

Integration-based Geometric Object	Curves: 2D	Curves: On surfaces	Curves: 3D Particle Tracing	Curves: 3D Rendering and Placement	Surfaces	Volumes
	[TB96]	[vW92]$_p$	[BS87]	[HP93]	[Hul92]	[SVL91]
	[JL97a]	[vW93a]$_p$	[RBM87]	[ZSH96]$_p$	[vW93b]	[MBC93]
	[JL97b]	[MHHI98]	[Bun89]	[FG98]	[BHR*94]	[XZC04]
	[JL01]	[SLCZ09]	[BMP*90]	[MT*03]	[LMG97]	
Steady	[VKP00]	[RPP*09]	[KM92]	[LWSH04]	[WJE00]	
Data	[LJL04]		[USM96]	[MPSS05]	[SBH*01]	
Field	[MAD05]		[LPSW96]	[LGD*05]	[GTS*04]	
	[LM06]		[SvWHP97]	[LH05]	[LGSH06]	
	[LHS08]		[SdBPM98]	[YKP05]	[PS09]	
			[SRBE99]	[CCK07]		
			[NJ99]	[LS07]		
			[VP04]			
	[JL00]		[Lan93]	[BL92]	[STWE07]	[BLM95]
			[Lan94]	[WS05]	[GKT*08]	
			[KL95]	[HE06]	[vFWS*08]	
Unsteady			[KL96]		[MLZ09b]	
Data			[TGE97]		[KGJ09]	
Field			[TGE98]		[BFTW09]	
			[TE99]			
			[SGvR*03]			
			[KKKW05]			
			[BSK*07]			

Table 1: *An overview and classification of integration-based geometric methods in flow visualization along the x-axis. Research is grouped based on the temporal dimensionality along the y-axis. Each group is then split into techniques that are applicable to steady or unsteady flow. Finally the entries are grouped into chronological order. Each entry is also colored according to the main challenge, as outlined in Section 1.1, that they address. The color coding scheme used is red for seeding strategies, green for techniques addressing perceptual challenges and yellow for methods aimed at improving application performance. The subscript "p" indicates visualization using particles. This table provides an overview of research and highlights unsolved problems as well as challenges for which a range of solutions have been provided.*

Breadth versus Depth

Focus here is on breadth

- PhD programs usually start with breadth
- Depth phase follows breadth phase: then more time spent on re-reading and understanding individual papers
- Page/space limits can prevent all details from being published
- Contact authors with questions
- Good research direction is difficult to judge based on single paper (unless reader is already an expert)
- Thus, surveys are good.
- Don't forget to check for existing survey papers.

Summary and Conclusions

Reading research papers and extracting essentials is a key skill acquired by PhD candidates

- Gathering information from scores or hundreds of previously published papers is very challenging
- We describe a process in order to help beginner achieve this goal
- Process described can form the basis of a survey paper
- Based on experience in both the classroom and in writing survey papers.

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For more information please see, **How to Read a Visualization Research Paper: Extracting the Essentials**, *IEEE Computer Graphics and Applications (IEEE CG&A), forthcoming*

Available online:

http://cs.swan.ac.uk/~csbob/research/starterKit/

Questions?