TOWARD EFFECTIVE ALGORITHM VISUALIZATION ARTIFACTS: DESIGNING FOR PARTICIPATION AND COMMUNICATION IN AN UNDERGRADUATE ALGORITHMS COURSE

by

CHRISTOPHER DAVID HUNDHAUSEN

A DISSERTATION

Presented to the Department of Computer and Information Science
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

June 1999

ABOUT THIS MANUSCRIPT

The following manuscript is a reformatted version of my original dissertation, which I defended in May of 1999 in the Department of Computer and Information Science at the University of Oregon. It is published as technical report number CIS-TR-99-07 (June, 1999) by the Department of Computer and Information Science, University of Oregon, Eugene. If you wish to have a hard copy of the technical report mailed to you, please contact Jan Saunders (jan@cs.uoregon.edu).

I am making my dissertation available on-line in hopes of better disseminating the work. I hope to publish pieces of this work as conference papers and journal articles; look for these to appear over the next few years. In the meantime, if you would like to cite this work, please use the designation "unpublished doctoral dissertation," and reference the technical report cited above.

I am still actively developing the prototype versions of SALSA and ALVIS presented in Chapter 7, and hope eventually to release them into the public domain. If you're interested in a status report on SALSA and ALVIS, of if you have any comments, questions, or feedback on any of this work, please contact me!

Chris Hundhausen
Postdoctoral Researcher
Laboratory for Interactive Learning Technologies
Department of Information and Computer Sciences
University of Hawai'i at Manoa
1680 East-West Road
Honolulu, HI 96822
hundhaus@hawaii.edu
http://lilt.ics.hawaii.edu/~hundhaus

Happy reading!

C.D.H.
Honolulu, HI
November, 1999

"Toward Effective Algorithm Visualization Artifacts: Designing for Participation and Communication in an Undergraduate Algorithms Course," a dissertation prepared by Christopher D. Hundhausen in partial fulfillment of the requirements for the Doctor of Philosophy Degree in the Department of Computer and Information Science. This dissertation has been approved and accepted by:

Dr. Sarah Douglas, Chair of the Examining Committee

Date

Committee in charge: Dr. Sarah Douglas, Chair
Dr. Christopher Wilson
Dr. Michal Young
Dr. Harry Wolcott
Dr. John Stasko

Accepted by:

Dean of the Graduate School

ABSTRACT

Algorithm visualization (AV) software graphically illustrates how computer algorithms work. While the software initially had much promise as a pedagogical aid, research studies designed to substantiate its pedagogical benefits have yielded markedly mixed results. I argue that to harness the pedagogical promise of AV software, we need to rethink the theory of effectiveness that has guided its design and pedagogical use. My starting point is an alternative theoretical foundation that views learning not at the level of the individual, but rather at the level of the community of practice. On this alternative view, learning is seen in terms of participating more centrally in the practices of the community.

To tailor this theoretical perspective to the particulars of the community of practice in which algorithms learning takes place, I conducted an ethnographic study of an undergraduate algorithms course in which AV software was used to facilitate students' more central participation in the community. Specifically, students were asked to use AV software to construct and present their own visualizations—two activities commonly performed only by community experts (algorithms instructors). The key finding of the study is that requiring students to use conventional AV software in this way actually impedes learning within the community, because it requires students to put inordinate amounts of time into community-irrelevant activities, and because it discourages students and instructors from engaging in meaningful conversations about algorithms. On the other hand, asking students to construct and present homemade visualizations made out of simple art supplies appears to avoid these problems.

To explore this finding further, this dissertation pursues two parallel research directions: (1) a controlled experiment that tests the hypothesis that, on a test of procedural understanding and recall, students who construct their own, homemade visualizations will outperform students who interact with a visualization constructed by an expert; and (2) a prototype AV system that supports the construction and presentation of unpolished, pen-and-paper visualizations. This research provides the beginnings of an alternative theory of effectiveness, which emphasizes the importance of students' constructing and discussing unpolished, pen-and-paper visualizations as a means of participating in a community of practice.

ACKNOWLEDGEMENTS

This epic journey would not have been possible without the help of several individuals. To begin with, I owe a big hug and kiss to my parents, Patricia and David Hundhausen, who have always been remarkably supportive of my interests, despite the fact that those interests have not always been understandable or interesting to them.

Lee Schmidt, my high school mentor, and Tom Naps, my undergraduate mentor, planted the initial seeds for my venture into computer science and research. Lee sparked my interest in computer programming in Pascal, while Tom sparked my interest in doing long-term research, and then patiently taught me how to do it during the four summers I helped him to build software for Lawrence University's algorithm visualization laboratory (NSF ILI grant #88-51781).

I am grateful to Walter Tichy for inviting me to pursue the preliminary stages of this research as a Fulbright Scholar in his Institute for Programming Structures and Data Organization at the University of Karlsruhe, Germany. During my "Traumjahr" there (1993-94), Arne Frick, Stefan Hänssgen, Rick Chamberlin, Delel Chaabouni, Christoph Jerger, Aida Chouchane, Karim Diab, Frederic Million, Fabien Fersing, and Richard Kupprion sustained me with much needed encouragement and friendship as I learned to live "auf die echte deutsche Weise" (in the true German way). When I arrived back in Eugene, Dr. Allen Malony advised and funded me during my first year in the Ph.D. program, while Gunnar Sacher helped me to maintain balance by beckoning me away from my computer for hiking and camping trips.

The ethnographic fieldwork and experiment presented in this dissertation would not have been possible without the enthusiastic participation of numerous CIS 315 students and their CIS 315 instructor; unfortunately, I cannot mention them by name. I am grateful to the University of Oregon's College of Arts and Sciences and Graduate School for two grants (the Mary Chambers Brockelbank Scholarship, and a Graduate Student Research Award) that paid the participants in the experiment presented in Chapter 6. The prototype language and system presented in this dissertation would not have been possible without the help of (a) Hank Bennett, who programmed the back-end animation engine and a significant portion of the user interface, and (b) fellow HCI lab member Ted Kirkpatrick, who furnished ingenious advice at times when the Microsoft® Foundation Classes had me really stumped. Ted also kept me honest during the statistical analysis of my experiment's data.

I am grateful to Harry Wolcott for getting me excited about ethnography, and for offering sage advice on the ethnographic research presented in this dissertation. I am grateful to John Stasko, one of the pioneers of algorithm visualization, for being such a wonderful remote collaborator and discussant throughout my graduate studies, and for serving on my committee. Last, but not least, I am deeply indebted to my inspirational advisor, Sarah Douglas, who challenged me while remaining encouraging all the way through, especially in the final months, when I needed her support the most.

My greatest thanks, however, goes lovingly to my best friend, life partner, and fiancée, Laura Girardeau, who has inspired me to grow in ways I could never have imagined. Despite my tendency to act as though algorithm visualization is the most important thing in life, she was able to see through to my true self, remaining passionate, patient, giving, and forgiving. Namaste!

DEDICATION

To my old self, who thought that he had to achieve to be loved

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