STCI: OptIPlanet Cyber-Mashup

Persistent Visualization and Collaboration Services for Global Cyber Infrastructure

NSF Award OCI-0943559

www.sagecommons.org

Annual Report September 1, 2010 – August 31, 2011
Submitted October 12, 2011

Jason Leigh, Maxine Brown, Andrew Johnson, Luc Renambot
Electronic Visualization Laboratory
University of Illinois at Chicago
851 S. Morgan St., Room 1120
Chicago, IL 60607-7053
spiff@uic.edu

Table of Contents

1. Participants

1.A. Primary Personnel

Participant's Name(s)	Project Role(s)	>160 Hours/Yr
Jason Leigh	Principal Investigator	Yes
Maxine Brown	Co-Principal Investigator	Yes
Andy Johnson	Co-Principal Investigator	Yes
Luc Renambot	Co-Principal Investigator	Yes
Lance Long	Senior Personnel	Yes
Ratko Jagodic	Graduate Student	Yes
Hyejung Hur	Graduate Student	Yes
HeeJoo Kim	Graduate Student	Yes
Viktor Mateevitsi	Graduate Student	Yes
Sungwon Nam	Graduate Student	Yes
JD Pirtle	Graduate Student	Yes
Sangyoon Lee	Graduate Student	Yes
Jon Chambers	Graduate Student	Yes

1.B. Other Organizations That Have Been Involved as Partners

King Abdullah University of Science and Technology (KAUST)
King Abdullah University of Science and Technology (KAUST) <www.kaust.edu.sa/> is an international graduate-level research university located in Thuwal, on the Red Sea in the Kingdom of Saudi Arabia. KAUST was inaugurated in September 2009 by King Abdullah, whose dream for more than 30 years has been to build a university dedicated to inspiring a new age of scientific achievement that will impact Saudi Arabia, the region and the world. To foster its growth, KAUST Global Collaborative Research (GCR) established Special Academic Partnerships (SP) with select institutions across the world to rapidly develop key laboratories and facilities on campus and initiate world-class research and programs in coordination with KAUST faculty. Through these Special Partnerships and other GCR Programs, KAUST has launched an active global research and education network geared towards solving challenging scientific and technological issues.

Sharp Laboratories of America
Sharp Laboratories of America (SLA) <www.sharplabs.com> is Sharp Corporation's first and only US-based research and development laboratory, focusing on the trends, technology issues, and product demands of North American markets in order to develop technologies to match. SLA sees a market for high-resolution interactive display systems in research laboratories and homes in the foreseeable future, and partners with the UIC Electronic Visualization Laboratory to learn how today's early adopters are using this technology.

Texas Advanced Computing Center
Texas Advanced Computing Center (TACC), University of Texas at Austin <www.tacc.utexas.edu>, enables discoveries that advance science and society through the application of advanced computing technologies. To fulfill this mission, TACC staff members assist research teams in properly employing the systems, software, and expertise necessary to foster educational innovation and to provide a greater societal impact. To support the world-class research, TACC provides advanced visualization resources and consulting services, including Stallion, one of the highest resolution tiled display walls in the world, and Longhorn, a very large, hardware accelerated, remote, interactive visualization cluster. EVL graduate Byungil Jeong, who received his PhD for SAGE and SAGE Visualcasting development, worked at TACC from 2008-2011. TACC had encouraged Jeong to work with EVL on SAGE development.

1.C. Other Collaborators or Contacts

The SAGE User Community currently consists of ~70 major research, education and corporate research sites worldwide that use SAGE and contribute to its development. Those institutions are:

AUSTRALIA

AARNet www.aarnet.edu.au
Australian National University http://information.anu.edu.au/daisy/infoservices/2085.html
CSIRO Discovery Centre http://research.ict.csiro.au/research/labs/information-engineering/ie-lab-projects/optiportal
CSIRO Information and Communication Technologies, Marsfield www.csiro.au/resources/CSIROvision.html
Monash University – Caulfield http://messagelab.monash.edu.au/Infrastructure/OptiPortal
Monash University – Clayton http://messagelab.monash.edu.au/Infrastructure/OptiPortal
University of Melbourne www.unimelb.edu.au/
University of Queensland www.vislab.uq.edu.au/research/optiputer

BRAZIL

University of Sao Paulo, Laboratory of Computer Architecture and Networks www.larc.usp.br

CANADA

Ciena Networks, Canada www.ciena.org
Communications Research Centre, Broadband Applications and Demonstrations Laboratory www.crc.gc.ca
Simon Fraser University www.sfu.ca

CHINA

Beihang University, State Key Lab of Software Environment Development http://www.nlsde.buaa.edu.cn
Chinese Academy of Sciences, Computer Network Information Center http://english.cnic.cn

CZECH REPUBLIC

Masaryk University, Laboratory of Advanced Networking Technologies (2 systems) www.sitola.cz/sitola/index.en.html

GERMANY

Braunschweig University of Technology, Institute of Computer and Network Engineering, Germany www.ida.ing.tu-bs.de

INDIA

Monsanto Research Centre (Bangalore) www.monsantoindia.com/monsanto/layout/researchcentre

JAPAN

Cybernet Systems Co. www.cybernet.co.jp/english
Kyoto University www.kyoto-u.ac.jp/en
National Institute of Advanced Industrial Science and Technology (AIST) www.aist.go.jp/index_en.html
NICT (National Institute of Information and Communications Technology), Koganei, Japan www.nict.go.jp/index.html
NICT, 5th Building, Koganei www.nict.go.jp/index.html
NICT, 6th Building, Koganei www.nict.go.jp/index.html
NICT, Keihanna Research Center, Kyoto http://kccc.nict.go.jp/keihanna-lab/en/
NTT Network Innovation Laboratory, Yokosuka www.ntt.co.jp/sclab/index_e.html
Osaka University, CyberMedia Center www.osaka-u.ac.jp/eng

KOREA

Gwangju Institute of Science and Technology (GIST) http://netmedia.gist.ac.kr
Korea Institute of Science and Technology Information (KISTI) www.ksc.re.kr/eng/index.htm

MEXICO
Ensenada Center for Scientific Research and Higher Education (CICESE) www.cicese.edu.mx

NETHERLANDS
SARA Computing & Networking Services www.sara.nl/index_eng.html
University of Amsterdam, System and Network Engineering Research Group
www.science.uva.nl/research/sne
University of Amsterdam, e-BioScience Laboratory www.micro-array.nl/ibu.html

NEW ZEALAND
Victoria University of Wellington http://ecs.victoria.ac.nz/EResearch/OptIPortal

RUSSIA
Russian Academy of Sciences, Science and Innovation Center
www.chernogolovka.org/eng_content/show_index.php
Russian Academy of Sciences, Space Research Institute http://arc.iki.rssi.ru/eng

SAUDI ARABIA
King Abdullah University for Science and Technology (KAUST) www.kaust.edu.sa

TAIWAN
National Center for High-performance Computing (NCHC) www.nchc.org.tw/en

UNITED STATES
Adler Planetarium & Astronomy Museum www.adlerplanetarium.org
Argonne National Laboratory, Center for Nanoscale Materials http://nano.anl.gov
Argonne National Laboratory, Nuclear Engineering Division www.ne.anl.gov
Argonne National Laboratory, Transportation Research and Analysis Computing Center
www.anl.gov/TRACC
Calit2/University of California, Irvine, HIPerWall www.calit2.net/about/info/uci
Calit2/University of California, San Diego, HIPerSpace Laboratory www.calit2.net
Calit2/University of California, San Diego, OptIPortable http://ivl.calit2.net/wiki/index.php/Infrastructure
Calit2/University of California, San Diego, OptIPortable2 www.calit2.net
Calit2/University of California, San Diego, Rocks/CAMERA www.calit2.net
Calit2/University of California, San Diego, SAGE Wall www.calit2.net
Casa Familiar www.casafamiliar.org
Extreme Networks www.extremenetworks.com
Florida International University, Center for Internet Augmented Research & Assessment www.fiu.edu
Louisiana State University, Center for Computation and Technology www.cct.lsu.edu
Monsanto www.monsanto.com
NASA Ames Research Center, Lunar Science Institute http://lunarscience.arc.nasa.gov/
NASA Goddard Space Flight Center, Space Visualization Studio http://svs.gsfc.nasa.gov
Northwestern University, International Center for Advanced Internet Research
www.it.northwestern.edu/about/departments/icair/index.html
Purdue University, Envision Center for Data Perceptualization www.envision.purdue.edu
Rincon Research Corporation www.rincon.com
Sharp Laboratories of America www.sharplabs.com
South Metro Career Center www.metrocareercenters.org
Texas A&M University, Computer Science www.cs.tamu.edu
United States Geological Survey (USGS) National Center for Earth Resources Observation and Science
http://edc.usgs.gov

UCSD (University of California San Diego), National Center for Microscopy and Imaging Research
www.ncmir.ucsd.edu
UCSD, Scripps Institution of Oceanography www.sio.ucsd.edu
University of Hawaii at Manoa, Center for Microbial Oceanography: Research and Education (2 systems)
http://cmore.soest.hawaii.edu
University of Illinois at Chicago, ACM Student Chapter (College of Engineering)
http://acm.cs.uic.edu/sigbuild
University of Illinois at Chicago, Electronic Visualization Laboratory, Cyber-Commons
www.evl.uic.edu/core.php?mod=4&type=1&indi=379
University of Illinois at Urbana-Champaign, National Center for Supercomputing Applications
www.ncsa.uiuc.edu
University of Michigan, Department of Atmospheric, Oceanic & Space Sciences
http://aoss.engin.umich.edu
University of Michigan, Digital Media Commons www.dc.umich.edu/dmc/
University of Michigan, School of Information www.si.umich.edu
University of Texas at Austin, Texas Advanced Computing Center
www.tacc.utexas.edu/resources/visualization/
University of Washington www.washington.edu

2. Activities and Findings

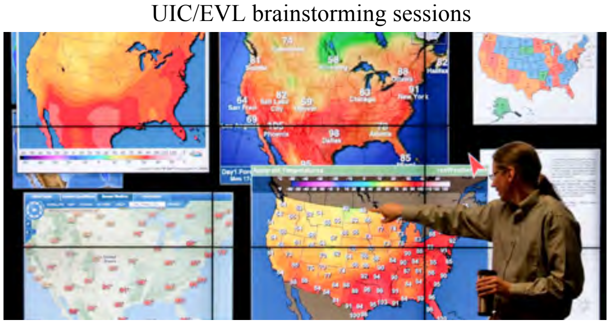
2.A. Research Activities

2.A.1. Overview

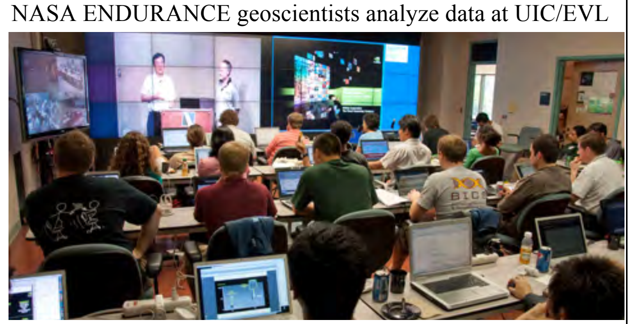
SAGE and tiled display walls are creating a global collaborative visualization environment that enables virtual teams of researchers to manage the scale and complexity of their data and work with one another. Presently, SAGE is transitioning from a research prototype to a hardened technology and creating new open services for visualization and collaboration utilizing shared cyberinfrastructure, as witnessed by the growth of the nascent SAGE User Community, with over 70 major sites worldwide.

UIC/EVL brainstorming sessions

NASA ENDURANCE geoscientists analyze data at UIC/EVL



UIC CS Visualization and Visual Analytics class compares various representations of the same dataset



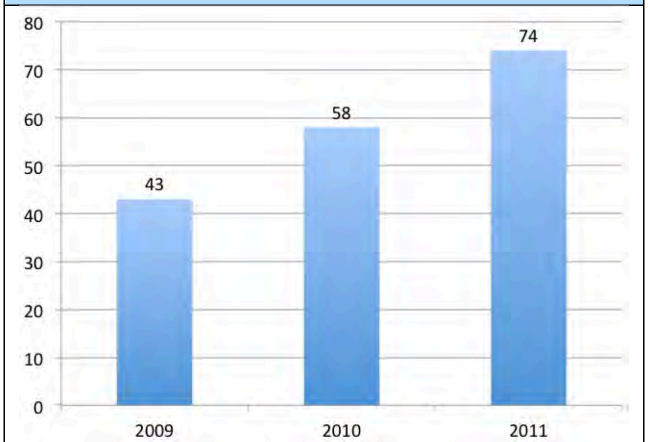
NCSA Virtual School's Many-Core Processor class was streamed to UIC/EVL's Cyber-Commons classroom

SAGE is cross-platform, open-source middleware that enables users worldwide to have a common operating environment, or framework, to access, display and share a variety of data-intensive information – whether digital cinema animations, high-resolution images, high-definition video-teleconferencing, presentation slides, documents, spreadsheets or laptop screens – in a variety of resolutions and formats, from multiple sources, to one or more tiled display walls, with the same ease that the Web affords for accessing lower-resolution objects today. To make tiled display walls easier to use, SAGE also provides automated assistance to users to organize information, especially as the quantity of content grows.

SAGE enables multi-user interaction and supports a variety of input devices; notably, laptop keyboards, the Gyromouse, joysticks, trackballs, 6 degree-of-freedom magnetic trackers, touch screens, the Nintendo Wiimote and the Microsoft Kinect.

2.A.2. SAGE User Community

Growth of SAGE Sites Worldwide

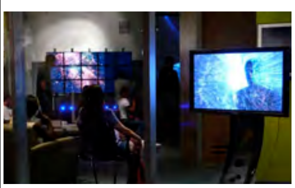
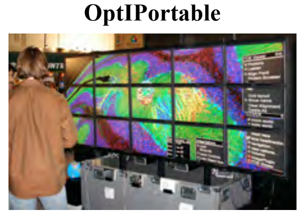


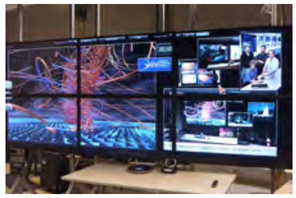
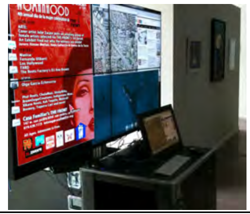
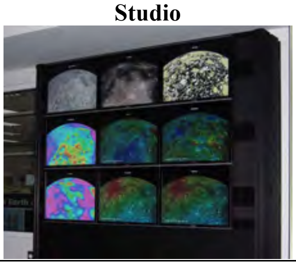
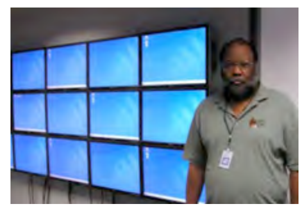
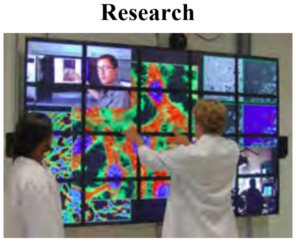
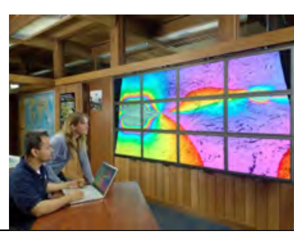
The number of international SAGE sites has been growing steadily since this STCI was awarded in 2009. While the following list is as up-to-date as we have, our users continue to build and deploy tiled display walls at their institutions, so the number of SAGE sites continues to grow.

Upcoming Sites…In addition to known sites, we are aware of SAGE being tested at the (1) Department of Computer Science at Georgia State University, who has a Windows 7 VizWall, (2) School of Computer Science at Costa Rica Institute of Technology, and (3) Technical Services group at Internet2. In addition, Brazil's RNP is purchasing a 4x2 tiled display wall to run SAGE and Japan's NTT Advanced Technologies (AT) division recently acquired a tiled display and is in the process of learning SAGE.

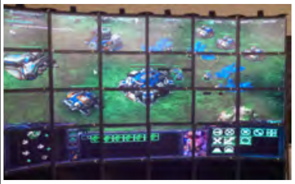
Not only is the SAGE adoption rate growing, but the types of users are growing. In its early years, the primary users of SAGE were scientists at academic and government research institutions. There are now more corporate users (e.g., Ciena, Extreme Networks, Monsanto, NTT and Sharp Laboratories of America – with recent interest from Disney and Lucasfilm/ILM), and there is a growth in the education market (universities, museums, community centers). We believe that this growth is because (1) EVL is working to make tiled display walls more affordable and easier to use, and (2) students and teachers can easily push their laptop screens to tiled display walls and access documents and web pages via wireless and 1Gbps interfaces.

US SAGE Sites

Adler Planetarium & Astronomy Museum 	**Argonne National Laboratory, Center for Nanoscale Materials** 	**Argonne National Laboratory, Nuclear Engineering Division** UNDER CONSTRUCTION	**Argonne National Laboratory, Transportation Research and Analysis Computing Center** 
Calit2, University of California, Irvine – HIPerWall 	**Calit2, University of California, San Diego – HIPerSpace Laboratory** 	**Calit2, University of California, San Diego – OptIPortable** 	**Calit2, University of California, San Diego – OptIPortable2** 

Calit2, University of California, San Diego – Rocks/CAMERA 	**Calit2, University of California, San Diego – SAGE Wall** 	**Casa Familiar, San Ysidro** 	**Extreme Networks** **UNDER CONSTRUCTION**
Florida International University, Center for Internet Augmented Research & Assessment 	**Louisiana State University, Center for Computation and Technology** 	**Monsanto (St. Louis, MO)** **UNDER CONSTRUCTION**	**NASA Ames Research Center, Lunar Science Institute** **UNDER CONSTRUCTION**
NASA Goddard Space Flight Center, Space Visualization Studio 	**Northwestern University, International Center for Advanced Internet Research** 	**Purdue University, Envision Center for Data Perceptualization** 	**Rincon Research Corporation** 
Sharp Laboratories of America 	**South Metro Career Center, San Diego** 	**Texas A&M University, Dept of Computer Science and Engineering** 	**United States Geological Survey (USGS), National Center for Earth Resources Observation & Science** 
University of California, San Diego, National Center for Microscopy & Imaging Research 	**University of California, San Diego, Scripps Institution of Oceanography** 	**University of Hawaii at Manoa, Center for Microbial Oceanography: Research and Education (Ampitheater)** 	**University of Hawaii at Manoa, Center for Microbial Oceanography: Research and Education (Meeting Room)** 

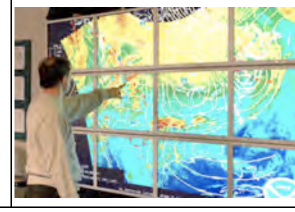
University of Illinois at Chicago, ACM Student Chapter (College of Engineering)



University of Illinois at Chicago, EVL – CyberCommons

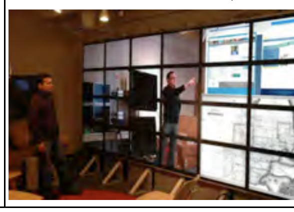
University of Illinois at Urbana-Champaign, National Center for Supercomputing Applications

University of Michigan, Department of Atmospheric, Oceanic & Space Sciences



University of Michigan, Digital Media Commons

University of Michigan, School of Information/ Provost's Virtual Space Interaction Testbed (VISIT)



University of Texas at Austin, Texas Advanced Computing Center

University of Washington

International SAGE Sites

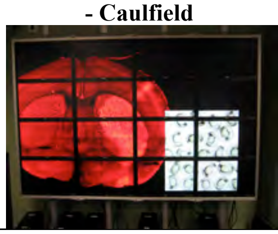
Australia, AARNet

Australia, Australian National University

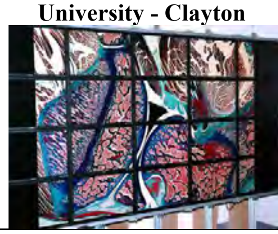
Australia, CSIRO Discovery Center

Australia, CSIRO Information and Communication Technologies, Marsfield

Australia, Monash University - Caulfield



Australia, Monash University - Clayton

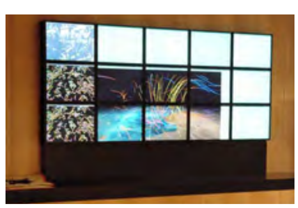


Australia, University of Melbourne ("OzIPortal")

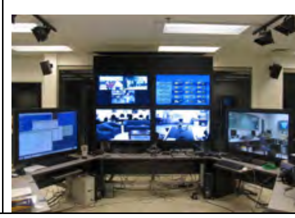
Australia, University of Queensland

Brazil, University of Sao Paulo, Laboratory of Computer Architecture and Networks (temporary wall)

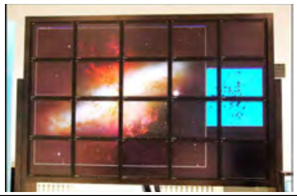
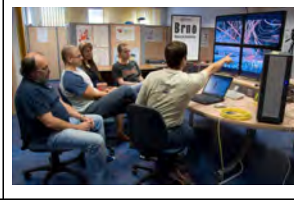
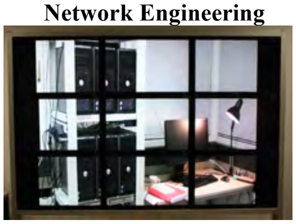
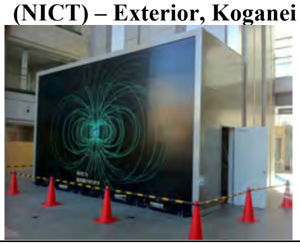
Canada, Ciena Networks

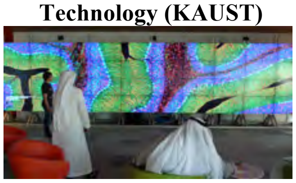
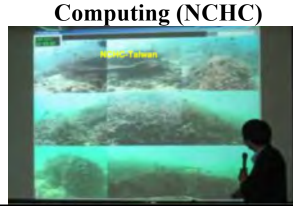


Canada, Communications Research Centre



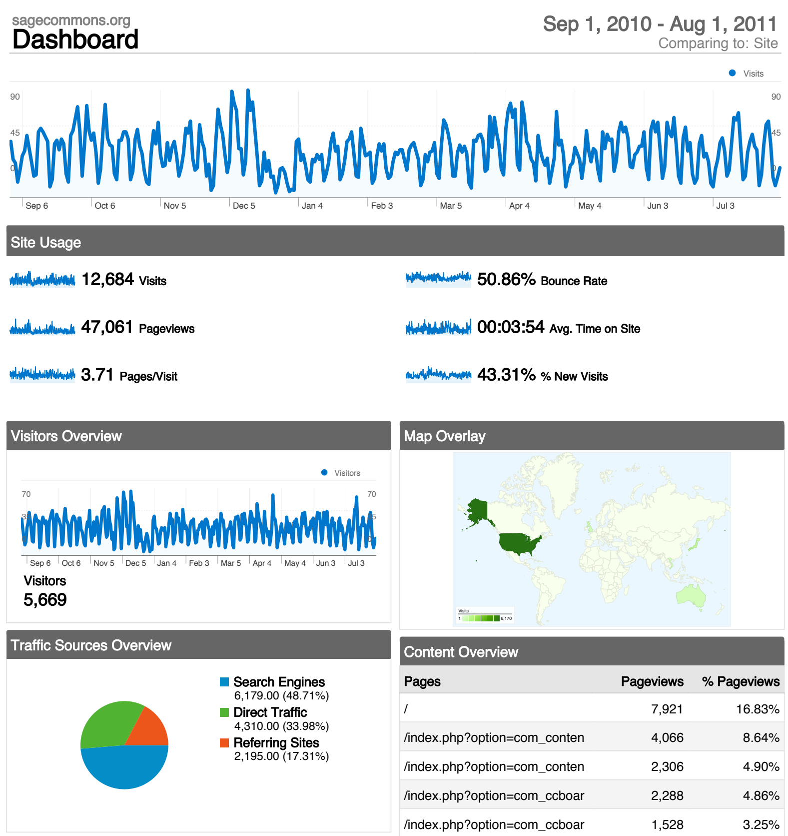
Canada, Simon Fraser University

China, Beihang University, State Key Lab of Software Environment Development 	**China, Chinese Academy of Sciences, Computer Network Information Center** 	**Czech Republic, Masaryk University, Laboratory of Advanced Networking Technologies (1)** 	**Czech Republic, Masaryk University, Laboratory of Advanced Networking Technologies (2)** 
Germany, Braunschweig University of Technology, Institute of Computer and Network Engineering 	**India, Monsanto Research Centre Bangalore** 	**Japan, Cybernet Systems Co., Ltd.** 	**Japan, Kyoto University** 
Japan, National Institute of Advanced Industrial Science & Technology (AIST) 	**Japan, National Institute of Info and Comm Technology (NICT) – Exterior, Koganei** 	**Japan, National Institute of Info and Comm Technology (NICT) – 5th Bldg, Koganei** 	**Japan, National Institute of Info and Comm Technology (NICT) – 6th Bldg, Koganei** 
Japan, National Institute of Info and Comm Technology (NICT) – Keihanna Research Center, Kyoto 	**Japan, NTT Network Innovation Laboratories, Yokosuka** **PICTURE NOT AVAILABLE**	**Japan, Osaka University, CyberMedia Center** 	**Korea, Gwangju Institute of Science & Technology** 
Korea, Korea Institute of Science and Technology Information (KISTI) 	**Mexico, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)** 	**Netherlands, SARA Computing & Networking Services** 	**Netherlands, University of Amsterdam, e-BioScience Laboratory** 

Netherlands, University of Amsterdam, System and Network Engineering Research Group 	**New Zealand, Victoria University of Wellington** 	**Russia, Russian Academy of Sciences, Space Research Institute** 	**Russia, Russian Academy of Sciences, Science & Innovation Center** 
Saudi Arabia, King Abdullah University of Science and Technology (KAUST) 	**Taiwan, National Center for High Performance Computing (NCHC)** 		

2.A.3. SAGE Website Statistics

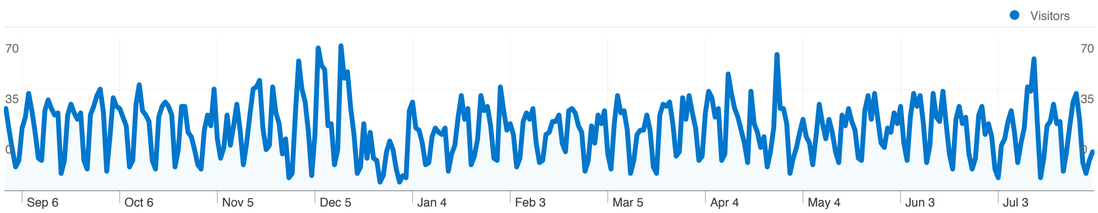
The SAGE website has general information, user locations, new versions of SAGE open-source software and a Forum on which users can post announcements or technical questions for discussion. Below are *Google Analytics* graphs of the weekly increase in traffic on the SAGE website for the period September 1, 2010 – August 1, 2011.



sagecommons.org

Visitors Overview

Sep 1, 2010 - Aug 1, 2011
Comparing to: Site



5,669 people visited this site

12,684 Visits

5,669 Absolute Unique Visitors

47,061 Pageviews

3.71 Average Pageviews

00:03:54 Time on Site

50.86% Bounce Rate

43.31% New Visits

Technical Profile

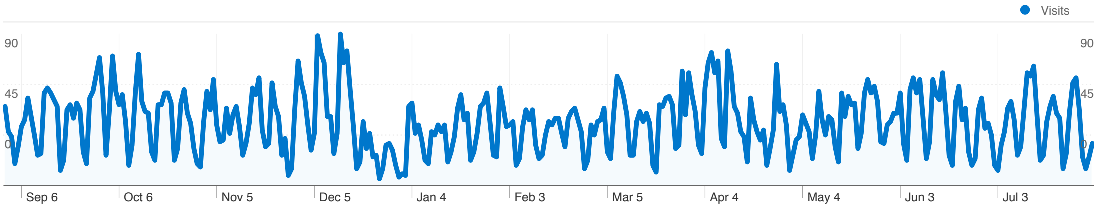
Browser	Visits	% visits
Firefox	6,256	49.32%
Chrome	2,701	21.29%
Safari	1,940	15.29%
Internet Explorer	1,541	12.15%
Opera	145	1.14%

Connection Speed	Visits	% visits
Unknown	7,701	60.71%
T1	2,923	23.04%
DSL	1,169	9.22%
Cable	814	6.42%
Dialup	58	0.46%

sagecommons.org

Traffic Sources Overview

Sep 1, 2010 - Aug 1, 2011
Comparing to: Site

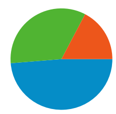


All traffic sources sent a total of 12,684 visits

 **33.98%** Direct Traffic

 **17.31%** Referring Sites

 **48.71%** Search Engines



- Search Engines 6,179.00 (48.71%)
- Direct Traffic 4,310.00 (33.98%)
- Referring Sites 2,195.00 (17.31%)

Top Traffic Sources

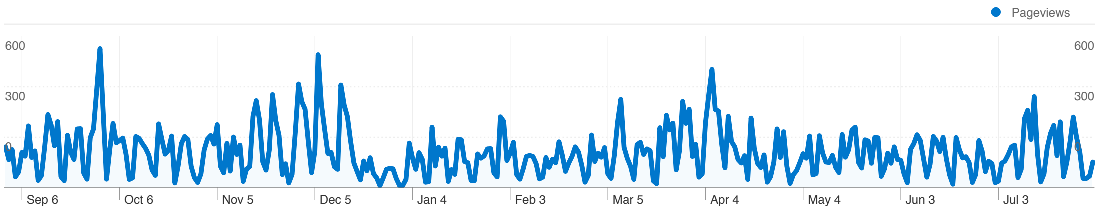
Sources	Visits	% visits
google (organic)	6,109	48.16%
(direct) ((none))	4,310	33.98%
evl.uic.edu (referral)	1,543	12.16%
sagecommons.org (referral)	78	0.61%
google.com (referral)	59	0.47%

Keywords	Visits	% visits
sage commons	746	12.07%
scalable adaptive graphics	318	5.15%
sagecommons	277	4.48%
sage evl	148	2.40%
sage display wall	88	1.42%

sagecommons.org

Content Overview

Sep 1, 2010 - Aug 1, 2011
Comparing to: Site



Pages on this site were viewed a total of 47,061 times

47,061 Pageviews

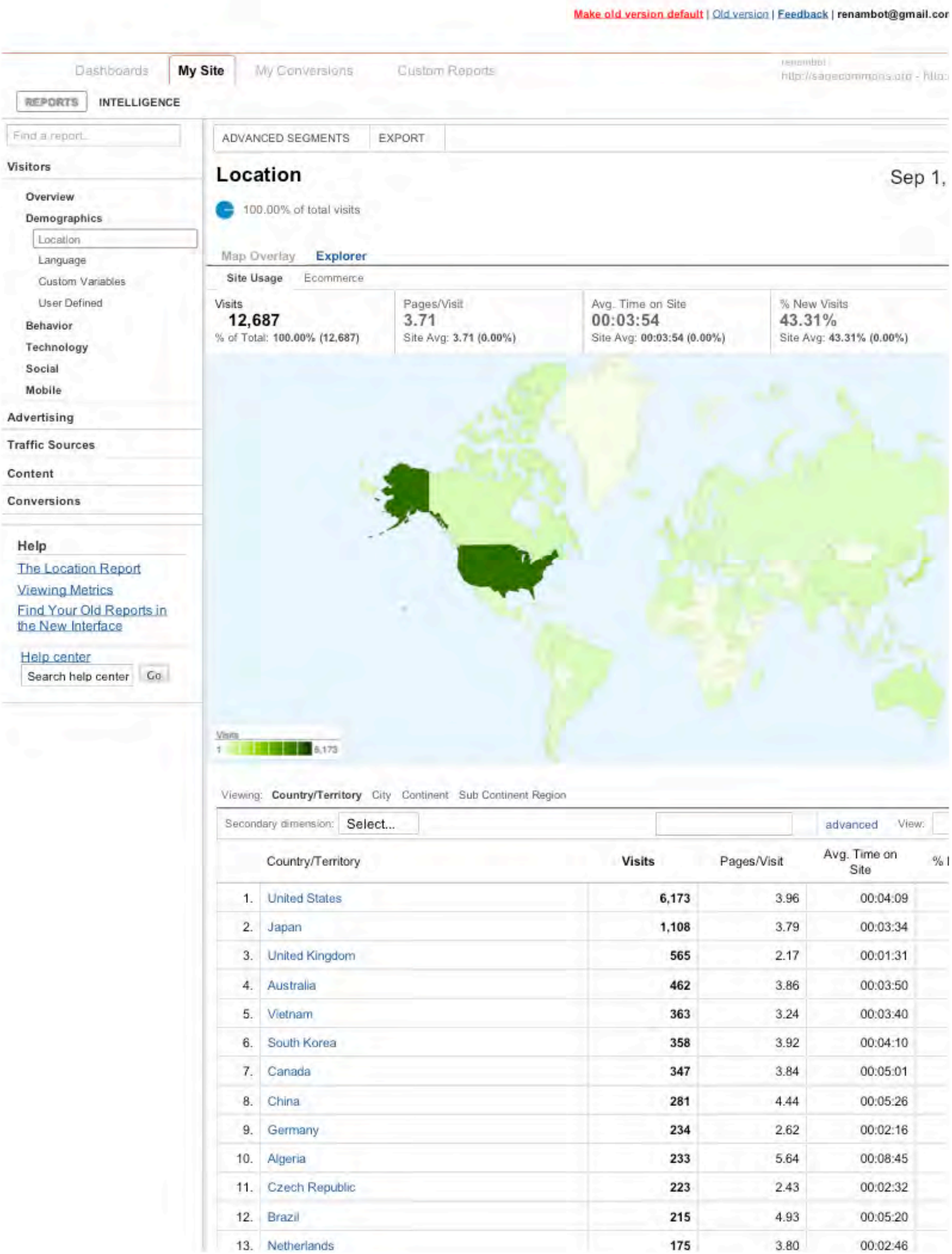
34,409 Unique Views

50.86% Bounce Rate

Top Content

Pages	Pageviews	% Pageviews
/	7,921	16.83%
/index.php?option=com_content&view=article&id=92	4,066	8.64%
/index.php?option=com_content&view=article&id=93	2,306	4.90%
/index.php?option=com_ccboard&view=forumlist	2,288	4.86%
/index.php?option=com_ccboard&view=topiclist&forum=5&Itemid	1,528	3.25%

▫



	Country/Territory	Visits	Pages/Visit	Avg. Time on Site
1.	United States	6,173	3.96	00:04:09
2.	Japan	1,108	3.79	00:03:34
3.	United Kingdom	565	2.17	00:01:31
4.	Australia	462	3.86	00:03:50
5.	Vietnam	363	3.24	00:03:40
6.	South Korea	358	3.92	00:04:10
7.	Canada	347	3.84	00:05:01
8.	China	281	4.44	00:05:26
9.	Germany	234	2.62	00:02:16
10.	Algeria	233	5.64	00:08:45
11.	Czech Republic	223	2.43	00:02:32
12.	Brazil	215	4.93	00:05:20
13.	Netherlands	175	3.80	00:02:46

14.	India	**174**	1.91	00:01:44
15.	France	**161**	3.14	00:02:20
16.	Colombia	**140**	4.83	00:05:22
17.	Italy	**136**	4.58	00:06:22
18.	Poland	**136**	4.98	00:08:02
19.	Saudi Arabia	**128**	2.95	00:03:18
20.	Russia	**112**	2.40	00:01:50
21.	Belgium	**74**	3.95	00:03:20
22.	Spain	**62**	1.97	00:01:04
23.	Mexico	**57**	3.53	00:07:16
24.	Taiwan	**49**	3.31	00:04:32
25.	Hong Kong	**47**	4.15	00:04:07
26.	New Zealand	**37**	5.78	00:02:28
27.	Sweden	**36**	2.81	00:01:46
28.	Turkey	**34**	3.53	00:04:10
29.	Switzerland	**27**	3.15	00:02:05
30.	Austria	**24**	2.12	00:02:57
31.	Ireland	**24**	1.75	00:00:32
32.	Israel	**22**	1.18	00:02:01
33.	Thailand	**20**	3.90	00:02:27
34.	(not set)	**20**	2.10	00:01:39
35.	Argentina	**19**	1.47	00:00:21
36.	Singapore	**19**	1.63	00:00:24
37.	South Africa	**18**	1.89	00:01:38
38.	Chile	**17**	6.06	00:07:19
39.	Sri Lanka	**17**	1.12	00:00:24
40.	Malaysia	**17**	1.35	00:00:59
41.	Nigeria	**16**	3.56	00:04:24
42.	Philippines	**16**	1.94	00:02:57
43.	Greece	**15**	1.47	00:01:27
44.	Portugal	**15**	1.20	00:00:44
45.	Ukraine	**15**	1.73	00:02:22
46.	Finland	**14**	1.50	00:00:27
47.	Romania	**13**	1.77	00:01:00
48.	Denmark	**12**	2.00	00:01:27
49.	Indonesia	**11**	3.55	00:03:05
50.	Norway	**11**	1.45	00:00:24
51.	Croatia	**9**	1.89	00:00:19
52.	Tunisia	**9**	1.22	00:00:04
53.	Bangladesh	**8**	1.88	00:01:00
54.	Egypt	**8**	1.00	00:00:00
55.	Hungary	**8**	2.12	00:01:12
56.	Slovenia	**8**	1.75	00:00:16

57.	United Arab Emirates	**6**	1.83	00:00:47
58.	Iceland	**6**	1.00	00:00:00
59.	Kenya	**6**	2.33	00:01:51
60.	Morocco	**6**	1.67	00:00:35
61.	Pakistan	**6**	1.83	00:02:08
62.	Iran	**5**	2.60	00:02:02
63.	Malta	**5**	1.00	00:00:00
64.	Bosnia and Herzegovina	**4**	1.50	00:00:31
65.	Bulgaria	**4**	1.25	00:00:14
66.	Estonia	**4**	1.00	00:00:00
67.	Jordan	**4**	2.00	00:00:44
68.	Latvia	**4**	3.00	00:02:39
69.	Puerto Rico	**4**	2.50	00:00:40
70.	Serbia	**4**	1.00	00:00:00
71.	Rwanda	**4**	1.25	00:00:04
72.	Slovakia	**4**	3.25	00:04:39
73.	Venezuela	**4**	1.75	00:00:36
74.	Belarus	**3**	1.67	00:01:29
75.	Kazakhstan	**3**	1.33	00:00:19
76.	Lithuania	**3**	1.00	00:00:00
77.	El Salvador	**3**	1.33	00:00:58
78.	Armenia	**2**	1.00	00:00:00
79.	Costa Rica	**2**	1.00	00:00:00
80.	Cyprus	**2**	1.00	00:00:00
81.	Georgia	**2**	2.00	00:02:55
82.	Ghana	**2**	1.50	00:00:36
83.	Guatemala	**2**	11.00	00:12:16
84.	Luxembourg	**2**	3.00	00:00:15
85.	Macau	**2**	2.00	00:00:03
86.	Nepal	**2**	1.00	00:00:00
87.	Qatar	**2**	1.00	00:00:00
88.	Sudan	**2**	1.00	00:00:00
89.	Syria	**2**	1.00	00:00:00
90.	Bahrain	**1**	1.00	00:00:00
91.	Brunei	**1**	1.00	00:00:00
92.	Ecuador	**1**	5.00	00:27:49
93.	Jersey	**1**	3.00	00:00:55
94.	Jamaica	**1**	1.00	00:00:00
95.	Lebanon	**1**	1.00	00:00:00
96.	Liechtenstein	**1**	3.00	00:00:16
97.	Lesotho	**1**	1.00	00:00:00
98.	Moldova	**1**	1.00	00:00:00
99.	Madagascar	**1**	1.00	00:00:00
100.	Mauritania	**1**	1.00	00:00:00

100.	[illegible]	1	1.00	00:00:00
101.	Mauritius	1	1.00	00:00:00
102.	Peru	1	4.00	00:23:53
103.	French Polynesia	1	1.00	00:00:00
104.	Paraguay	1	3.00	00:03:22
105.	Trinidad and Tobago	1	1.00	00:00:00
106.	Uganda	1	4.00	00:02:07
107.	Uruguay	1	1.00	00:00:00
108.	Vanuatu	1	1.00	00:00:00

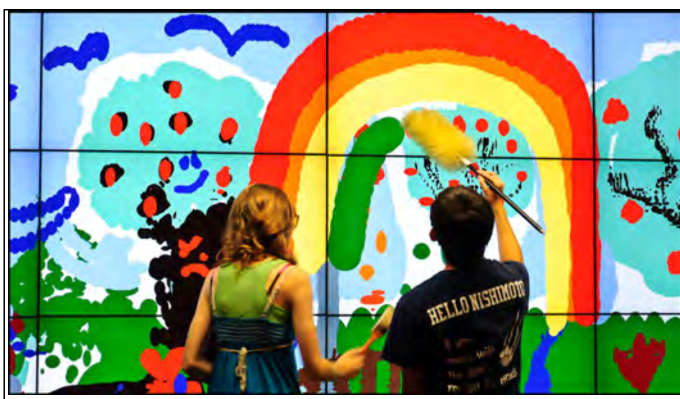
Show rows: 500 Go to:

2.A.4. SAGE and OptIPortables

EVL partner Calit2 developed a portable 2x2 tiled display wall, called an *OptIPortable,* which folds up into its own shipping case. (The term comes from the NSF-funded OptIPuter project, which dubbed tiled display walls as "portals" into the OptIPuter, or *OptIPortals.)* Two of these portable optical-network-enabled walls can be connected together to form a 2x4 tiled display wall. OptIPortables run SAGE. EVL helped configure a touch screen interface for the 2x4 unit. OptIPortables are easy to ship for demonstrations and presentations. Several groups have built OptIPortables, including NASA Ames and University of Sao Paulo.

Two OptIPortables next to each other form a 2x4 screen system. Note the shipping case below each of the 2x2 screens. Screens fold backward and slide down into the case for shipping. Photo: Tom DeFanti.

2.A.5. SAGE and New Input Devices (Touch Screens, Kinect, Vicon)



High school students using the Paint Program on EVL's Cyber-Commons tiled display wall.

Students playing "Fleet Commander" on EVL's Cyber-Commons tiled display wall.

When EVL first purchased a PQ Labs' Touch Screen for its Cyber-Commons' tiled display wall, it had students develop non-SAGE applications to test the limits/constraints of the technology. One of the applications was a Paint Program developed by REU undergraduates and graduate students; there is a YouTube video explaining it <www.youtube.com/evltube#p/u/6/lq6ShJnwr1Y>. The other was a multi-user videogame "Fleet Commander," written in Processing, developed by EVL graduate student Arthur Nishimoto; a YouTube was posted to YouTube <www.youtube.com/evltube#p/a/u/0/6V0o3TjB2Tw> and has gone viral. There are currently more than 640,000 hits.

EVL is also experimenting with both the Microsoft Kinect and the Vicon camera system for more natural user input. With the Kinect, "you are the controller,' as the Microsoft ads state. Kinect, and more recently the Vicon camera system, make perfect interfaces for SAGE. With the wave of a hand, scientists can control the size and position of SAGE's windows on large tiled display walls.


SAGE has a Kinect interface to allow users to select windows with their hands.

2.A.6. SAGE Code Releases

There are two versions of SAGE available for download from the SAGE website. SAGE "classic" (the open-source version) and SAGE "advanced" (with the new Graphical User Interface available as Linux binaries). SAGE's overall performance has been improved, such that more content and higher-resolution content can be shown simultaneously, user interaction is faster, and new physical interaction devices have been integrated (Section 2.A.5). There is also significant improvement in desktop sharing performance.

EVL has provided binary releases: for Scientific Linux 6, a Linux distribution used in the HPC community, Ubuntu 10.04, prototype Ubuntu 10.10 and 11.04; and, a bootable CD based on Suse 11.4 that installs the OS and SAGE for single computers.

2.A.7. SAGE Multi-user Interaction

2.A.7.1. Collaborative Multi-user Interaction on Tiled Wall Displays

The benefits of tiled display walls can only be achieved through the design of a user interface that is informed by the way people work in environments surrounded with content. Prior research has shown that well-established desktop interaction techniques generally do not scale to larger displays, motivating the need for new approaches. For tiled display walls, prior efforts were directed at addressing the issues of target acquisition, cursor tracking, gesturing and pointing, mostly with single users in mind. However, given that vast quantities of content can potentially be posted on tiled walls, there is a need for approaches to help users, especially those working in teams, to easily and concurrently manipulate and organize the content. ***In this regard, the SAGE user interaction design embodies the most comprehensive understanding of this problem to date and is the only one that supports tiled display walls.***

This year, EVL student Ratko Jagodic received his PhD for the SAGE interaction framework. It is built on top of SAGE and enables multiple users to simultaneously interact with local and/or remote media and applications, using a variety of physical interaction devices and scalable, distributed user interface widgets. Besides providing more intuitive interaction techniques for experienced and casual users of display walls, this framework enabled us to further study high-resolution environments in real-world scenarios, uncovering novel work paradigms and developing more appropriate interaction and display space organization techniques.

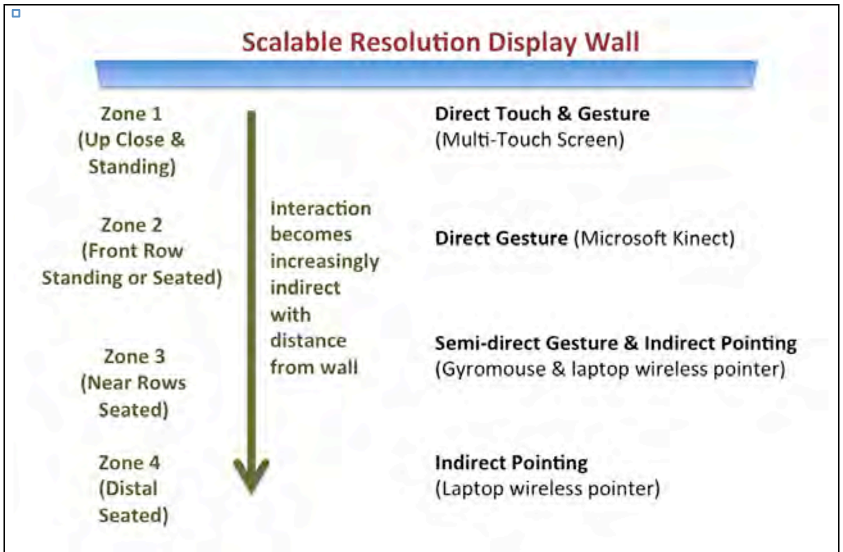
Based on war room affordances and preliminary experiences with SAGE and EVL's tiled display wall, the following fundamental design aspects of a direct interaction framework were identified:

- **Distributed:** User interfaces can be automatically displayed and interacted with across any number of displays, driven by any number of machines.
- **Scalable:** As the size and resolution of scalable displays varies, it is imperative that the interaction system adapts to the target display size and resolution from the perspective of visibility and usability.
- **Multi-user:** Generally, empowering every user with control minimizes social barriers for participation by eliminating the need to request control or interfering with other users. This, in turn, promotes discussion and fosters collaboration. Additionally, individual control facilitates task division among group members, potentially benefitting group performance through a greater degree of parallelism.
- **Multi-modal:** Given the potential applications of scalable displays, it is unlikely that a single input modality will satisfy interaction requirements for every use case. The choice of interaction modality depends on the number of users, the display size and the mobility of users in front of the display.

2.A.7.2. SAGE Interaction Framework

Interaction Zones

Various devices, such as touch screens, Gyromouse, trackpad, 6 degree-of-freedom tracked wand, Nintendo Wiimote, Microsoft Kinect, Vicon camera system, and wireless laptops/tablets, have all been examined as candidates for interacting with tiled display walls. Our observations of users suggest that as the distance between the user and the wall increases, the preference for indirect interaction increases. For example, when a user is up-close to the wall, it is most convenient to be able to reach out with one's hand and directly touch the image on the wall, whereas a user who is seated far from the wall would prefer to manipulate the information on the wall using the mouse pointer on their laptop to remotely control a pointer on the wall.



Four major interaction zones for user interactions with tiled display walls.

SAGE Pointer

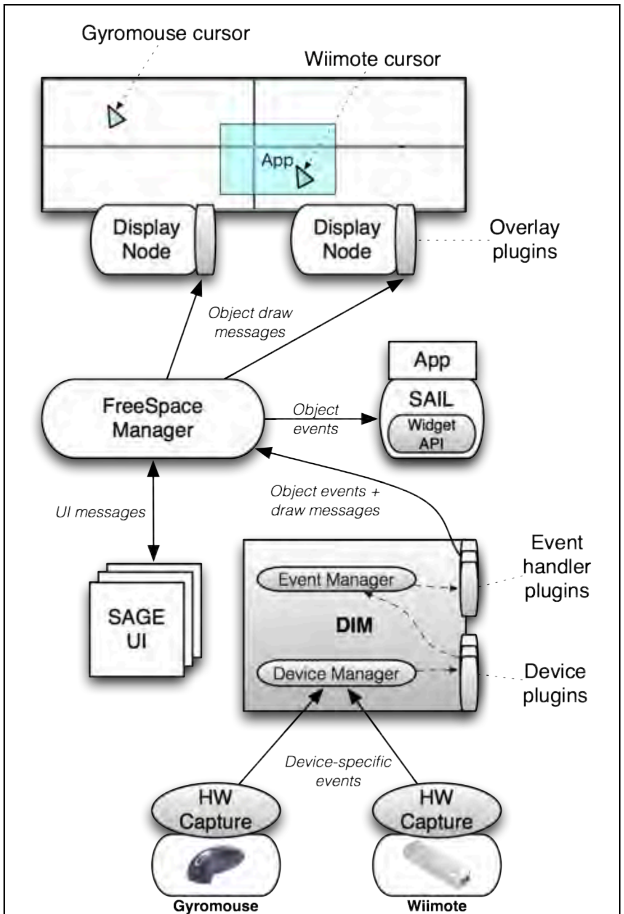
While there is a need for interaction modalities appropriate for a large number of users, providing every user with a physical interaction device is impractical. SAGE Pointer, a small cross-platform application (Windows and Mac), allows users to share a variety of image and video formats – PDF documents and personal desktops – using a VNC protocol from their laptop. It allows users to simultaneously manipulate windows on the wall by providing every user with their own pointer, controlled by the laptop's trackpad or mouse. To gain control of the wall, users simply move their cursor to the top portion of the laptop screen at which point their cursor shows up on the wall and disappears from the laptop screen. This metaphor is similar to the one of an extended monitor when a secondary display is connected to a laptop.

Besides sharing local media files and documents using a simple drag-and-drop interface, users can also share images and YouTube videos directly from a web browser, eliminating the need to first download them onto their computers. Furthermore, for information that cannot be uploaded to SAGE, users can take a local screenshot, which can automatically be shared on the wall by the SAGE Pointer application.

Physical Interaction Devices

To successfully enable multi-user interaction, SAGE's interaction system, the Direct Interaction Manager (DIM), accepts events from multiple physical interaction devices through a network interface. *Note: The DIM was described in detail in the previous annual report.*

If multiple devices are used in a system, especially if they are of different types, it is often the case that they are connected to multiple computers receiving their events (e.g., a special machine for the camera tracker), which necessitates network-based communication. A Hardware (HW) Capture component contains plugins for each device that captures the device-specific events, which are then delivered to DIM. The event delivery (messaging) library is already provided, so developers only need to create the plugin to capture device-specific events. To provide robust service, the DIM dynamically adds new devices and removes old ones if they fail or disconnect – enabling users to freely join and leave the space as they please, which mimics traditional war room environments.



DIM handles multiple physical interaction devices, Event Manager performs event distribution for device events, individual event handlers manage the logic, and overlays manage the drawing of objects. The components in gray are all part of the DIM.

All device-specific events are converted to a generic set of events, which in turn allows heterogeneous devices to interact with the display equally. Naturally, some devices are more powerful than others, so they can generate a larger subset of the generic events. These generic events are then put in an event queue where the Event Manager processes them in order, trying to find an appropriate event handler for each. If an Event Handler is found, the event is passed onto the Handler; otherwise, the event is discarded. Event Handler is the base class for any interactive object that wants to receive events. Essentially, it is a rectangular container that has size, position and depth parameters, knows how to receive events and it contains other properties common to all widgets (e.g., tooltips, labels, visibility flags).

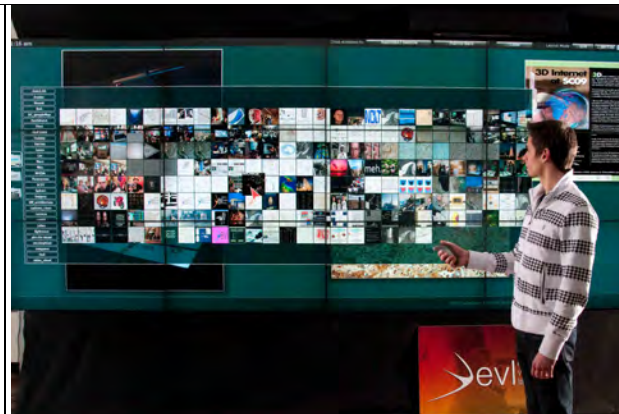
There is also an Event Handler for every application, which delivers interaction events to the actual application, whether it is local or remote (for instance, a dragging event can be delivered to a map application). Since the applications can be freely resized and repositioned on the display, all the event coordinates are normalized before being sent to the applications, as they are unaware of their own window position and size. While an Event Handler is processing an event, the Event Manager will lock it in order to prevent competition from different devices (for instance, if a button is held down or something is being dragged). However, no such restrictions are imposed between different event handlers, which allows for true multi-user interaction.

So far, no single device has emerged as the best tool for large-scale, high-resolution display environments even though studies have been performed using laser pointers, hand gestures, touch screens and traditional mice. We therefore found it necessary to allow the use of a wide variety of devices, even though they may generate different events.

SAGE Widgets

The DIM provides a framework for integrating multiple devices and for a functional, though very limited, direct interface to SAGE. However, to create a more complete interface, either for the wall or for applications (e.g., buttons), we developed SAGE Widgets to allow all applications, and the display itself, to use the same set of widgets without dealing with the event handling, the drawing, and the interaction devices being used, or the distributed nature of the environment. ***The initial set of widgets includes: button, icon, label, menu, panel and sizer.***

The above "movie" buttons enable users to control the animation using the touch screen overlay on the wall.



Users click/touch "folder" icons on leftmost wall to get a directory of accessible pictures, movies, screen shots, etc.

SAGE Widgets were never meant to be a complete set of widgets for building application interfaces, but rather a testbed for exploring human-factor issues that traditional widget toolkits will not allow. The widget framework was designed to be compatible with the existing DIM architecture, where each widget is actually a collection of several distributed elements.

2.A.8. Reconfigurable Display Space Organization

A user partitions on the workspace in SAGE by drawing wall dividers with his finger.

Overlapping windows on traditional desktop displays become more visible windows on tiled display walls, meaning that the problem of window switching now gives way to the problem of window organization. Compounded by the fact that large-screen real estate will inevitably entice users to juxtapose more information, one must examine better ways to help users organize this information into meaningful arrangements. SAGE provides a number of features toward this end, such as resizable horizontal and vertical partitions for dividing the wall into smaller workspaces that can be managed independently. A tiling feature automatically keeps windows within a specified workspace organized in a logical grid, or minimizes windows crossing over physical display mullions. SAGE also enables the content on the wall to be saved to enable users to continue working at a later time, or in the event of a computer or power failure. Managing an increasing amount of visible information requires more powerful window organization techniques. Several opportunities for improvement have been observed, which motivated the development of the following initial set of organization techniques.

Minimize – Off-loading Information

Although similar to the iconize feature found on desktops, the *minimize* feature was tailored for wall-sized displays. The minimize bar was positioned at the bottom, along the whole width of the display. To minimize a window, users simply drag the window down onto the minimize bar. SAGE minimized windows are not "iconized" as they typically are in desktop operating systems; instead, they are simply rescaled to a smaller size. For example, if a video is minimized, it will still be playing (albeit at a lower frame rate to preserve system resources). Given the large number of potential windows that can be open in SAGE at one time, this feature aids significantly in window identification, especially since the window aspect ratio is preserved as well. To take advantage of a user's spatial memory, a minimized window is positioned at the same location where the user dropped it onto the minimize bar. This further facilitates window identification. Windows minimized in the same area are also tiled, preventing overlap. Though tiling alters the window's minimized position slightly, it is not significant enough to invalidate a user's spatial memory. A single click on the minimized window restores it to its original position.

Maximize

Perhaps another term for *maximize* in the context of wall displays is "bring into focus," as maximizing a window over the whole display is rarely desired. Furthermore, one might imagine the utility of maximizing a window only within a physical display (i.e. one tile), however, in case of Cyber-Commons and its thin bezels, users typically regard the whole display as one seamless surface without paying much attention to the physical screens. Since we deal mostly with media files in SAGE, the *maximize* feature simply brings the window into the center of the display and makes it as large as possible while preserving the window's aspect ratio. Double-clicking anywhere on the window maximizes it while a second double-click restores the window to its original position.

Tiling

Although the large size and high resolution of tiled display walls enables us to juxtapose many pieces of information for direct comparison, it is time consuming to do manually. We developed a *tiling* feature to organize all the visible, un-minimized windows into a grid, with each cell being of equal proportions. The final cell size is determined from a combination of the average window aspect ratio, the aspect ratio of the display and on the number of visible windows. Although not optimal, it provides fairness given a variety of window sizes and their aspect ratios. Originally we had a second tiling mode, which used physical screen boundaries as cells, however, no one at EVL used this mode on our Cyber-Commons' display. Perhaps this suggests that 7mm bezels are small enough to perceive the display as seamless.

Tile mode can be turned on or off. Even when on, windows can still freely be moved and resized manually, allowing for further layout customization. When on, upon adding new content, the display automatically retiles itself. Turning the tiling mode off disables new window tiling but preserves the current organization of windows. The order of windows in the grid is based on the age of the window (i.e., how long the window has been on the display), the oldest being first, the youngest last. This is beneficial when new content is added to the display, as it shows up at the end of the grid without destroying the ordering and therefore spatial memory.

Multi-window Manipulation

As it is tedious to manipulate a large number of windows individually, we developed simultaneous *multi-window manipulation,* much like with icons on the desktop. This applies to moving, resizing, maximizing, minimizing and closing actions. Using the secondary click (e.g., right-click), one can drag-select, click-select or use a combination of both actions to select multiple windows. Moving, resizing and closing actions are replicated to multiple windows, similar to icons on the desktop. Minimizing multiple windows simultaneously brings all the windows into the same area within the minimize bar, which serves as a temporal reminder that a set of windows was minimized together. Maximizing a set of selected windows takes all of the windows on top of the others and tiles them using the same algorithm described previously. This essentially juxtaposes all selected windows for direct comparison. Multiple users can make their own selections and perform multi-window manipulations independently.

Push-to-back

In a desktop environment, reaching for a window completely hidden below the window in focus can easily be done using the ubiquitous ALT-TAB window switching operation. On tiled display walls, however, we need a different window switching operation since the user's mobility requirements make keyboards impractical. Although the top window could simply be moved aside to reveal hidden windows, it could also be pushed below all the windows without a change in size or position. While similar to the ALT-TAB operation, it does not switch to the most recent window but simply pushes the top window to the back, revealing the window immediately underneath. This way, the operation is localized and does not affect the layout of windows in other areas of the display.

Persistence

Although low-level support for persistence had previously been developed and found useful for a UIC anatomy class using EVL's display wall, we simplified its use by designing its interface using SAGE Widgets. We designed a media library to keep track of all the files shared by the users. This allows users to go back in time and browse older media directly on the wall, which is presented as thumbnails sorted by type and time of upload. Besides browsing the media, users can preserve the current state of the wall, which saves the position, size, and the loaded files of every application window currently running. Saved states can later be easily identified by a wall screenshot captured during saving. For reliability reasons, the system also automatically saves the state after every window manipulation, which can be reloaded in case of crashes to bring the wall to the exact state it was in right before the crash.

2.A.9. Display Partitioning and Up-close Interaction

Touch Interaction

Although the Gyromouse has been used for the bulk of interaction, when users are at arm's length from the display, it becomes somewhat confusing to use because small movements of the mouse result in large movements on the display. In such cases, directly interacting with the wall using touch gestures is more natural since it takes advantage of physical navigation. Having a PQ Labs' touch-screen device in our interaction framework allowed us to design and prototype multi-user, multi-touch gestures. Users now have the ability to interact from a distance (Gyromouse, Wiimote or SAGE Pointer) and interact from up-close using touch input; and, each input modality has different strengths and weaknesses.

We considered how to best design a wall's user interface so that it is appropriate for all input modalities. For instance, Gyromouse and Wiimote, although imprecise, can quickly traverse large distances. On the other hand, touch input can be precise but it takes a long time to drag an object across a 20-foot wall. We began by replicating the existing window manipulation functionality using touch gestures:

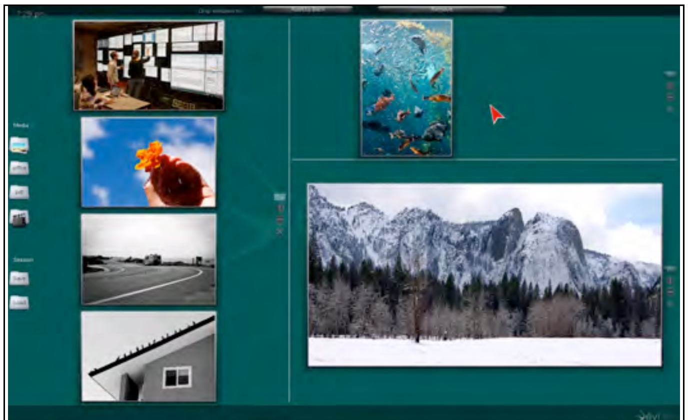
- **Move:** The intuitiveness of touch interfaces comes from a direct relationship between the action and the result. For instance, if a finger moves 2 inches, the object being acted upon should move 2 inches, as it would in real life. However, on a 20-foot wall like Cyber-Commons, this means the user would have to walk 20 feet in order to move a window from one side of the wall to the other, which would quickly become tedious given a large number of such actions. As a better approach, we designed two alternate solutions, an imprecise one and a precise one. The imprecise solution involves a single-finger flick gesture that launches a window as if it was thrown across the display. The speed of the flick determines how far the window will travel, while the direction of the flick determines the direction of the throw. This approach retains its roots in the real world and is easily understood since it mimics throwing real objects. The second approach allows users to precisely position a window anywhere on the wall, without having to walk the distance. A single-finger drag motion will drag a window at an accelerated pace according to a gain factor; e.g., given a gain factor of two, a one-inch movement of the finger will move the window two inches. The gain factor is determined dynamically based on the display size, satisfying the scalability characteristics of the interaction framework. While some users expressed skepticism about the intuitiveness of this method, they quickly realized its benefit and noted that the gesture actually makes a lot of sense.
- **Resize:** Resizing is performed using a familiar two finger-pinch gesture (similar to the iPhone). However, during pilot testing, users would attempt a pinch gesture with two hands at a distance significantly larger than the distance between two fingers on the same hand. Therefore, the size range of acceptable pinch gestures was increased to include two-handed attempts as well as the standard two-fingered ones.
- **Close:** To close a window using a physical interaction device, the user drags and drops the window on a *close* button at the top of the wall. Although possible to do with the touch interface, we felt there should be an easier way of accomplishing the same task. Therefore, a five-finger hold on the window will start fading the window. If the window reaches complete transparency after about one second, it will be closed, otherwise the close operation will be canceled and the window will return to normal opacity. Although not rooted in a real-life gesture, it has the benefit of requiring five fingers, which are rarely used during regular window manipulations and therefore not easily initiated by accident.
- **Maximize:** To maximize a window, the user double-taps it, much like double-clicking with other interaction devices.
- **Minimize:** Windows are minimized by dragging or flicking them to the bottom minimize bar. While the close button also requires dropping a window onto it, it is significantly smaller in size than the display-sized minimize bar, which was the reason for introducing a separate closing gesture. In order to make space on the display, we developed a gesture for minimizing all the windows at once. A five-finger downward swipe will begin "pulling a curtain" over the windows and, if the swipe is continued and the curtain reaches the bottom, all the windows will be minimized.
- **Push-to-back:** Pushing a window to the back is performed using a big tap, a tap with a large surface area. Users typically use the whole palm of their hand or the bottom of their fist. This somewhat mimics real-life gestures where a bigger push is expected to move objects further away, and since a tap is not directional, the object being acted upon can only go into the screen.

Display Sections

Prior research has shown that users take advantage of the physical bezels on tiled display walls for partitioning their workspace, typically into focal and peripheral regions. While Cyber-Commons has small physical bezels, so was treated as a seamless, contiguous surface, users still had a need to logically partition the wall into different sections, independent of the bezels. As near-seamless and seamless large high-resolution displays become more prevalent, we cannot rely on the organizational benefits of distinct physical screens. Therefore, to aid in spatial organization on such displays, we developed sections to explicitly partition a wall into any configuration of rectangular regions. This approach is similar to organizing documents (or files) in a folder, however, information on the wall is still visible, which gives it a dual purpose: it acts as a document itself while its section membership embeds a secondary meaning (e.g., time or category).

Sections are resizable rectangular regions that allow for simultaneous yet different organizational strategies on one seamless wall surface. To create a section, one splits any section into two, vertically or horizontally. This process can be repeated, allowing for any arrangement of sections on the wall. Removing a section is done using a small *close* button in each section, which simply assigns all its windows to the parent section. Each section can be tiled independently and will be retiled automatically if a new window is dropped into it while the tiling mode is turned on. When a window is dropped into a different section, it is automatically resized to fit within that section. Similarly, when sections are resized, all the windows within the section and the neighboring sections are moved and resized accordingly. The section membership is determined by the position of window's center. Manually moving and resizing windows within a section is still possible, although if the center of the window happens to fall outside the current section during a resize operation, the window will be automatically fitted into the new section.

With the introduction of sections, several previously described features were adjusted to better support selective organization strategies that sections offer. Minimizing multiple windows using a five-finger swipe gesture now acts only on the section where initiated, minimizing the windows within that section only. Similarly, a double-click (or tap) first maximizes the window within its section while a second consecutive double-click maximizes the window over the whole display. Lastly, the persistence feature also saves the current state of sections, even if no windows on the display are present. This allows users to preserve the current section arrangements as templates for later use.

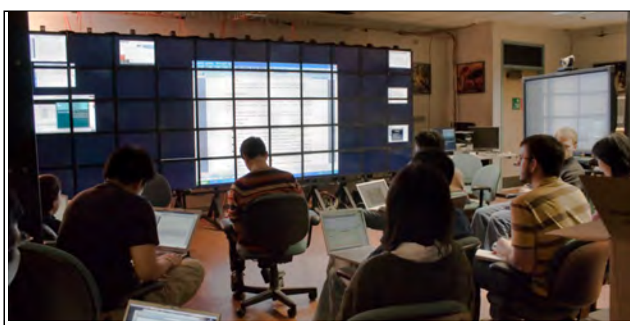


Three display sections support different organizing strategies. Left section is automatically tiled while others are manually organized.

2.A.10. Use Cases: Collaborative Analysis User Studies

Tiled display wall scenarios, such as presentations, meetings, classrooms and a simple analysis task, presented the need for manipulating numerous pieces of information, which informed the development of the interaction and display space organization techniques described in this report.

Previous Use Cases: Presentations, Meetings, Classroom



During weekly EVL technical research meetings, students show their laptop screens on the LambdaVision tiled display to share ideas and promote discussion.

In a UIC anatomy class study session, students answered questions using the displayed images on LambdaVision.

UIC Visual Analytics course held in the Cyber-Commons room. The left half of the wall contained lecture notes; the right half used SAGE to juxtapose media relevant to the lecture.

In the UIC Visual Analytics class, the teach juxtaposes media, externalizing students' memory and allowing direct comparison.

Use Case: Collaboration

Recently, EVL conducted a study to analyze collaboration use. The task was *job searching,* which involved surveying the then-current job market and finding the top five job openings given a variety of career interests and job criteria. This task was chosen because it required little specialized domain knowledge; it was simple and doable in a reasonable amount of time and potentially involved reviewing many pieces of information. The task was split into two parts in order to explore the two modes of group work we were interested in: working independently (dividing the work) and working together.

Eighteen (4 female, 14 male) EVL computer science students were recruited for the study, and organized into six groups with three participants in each group.

The goals of the study were to try to answer some of the following questions:

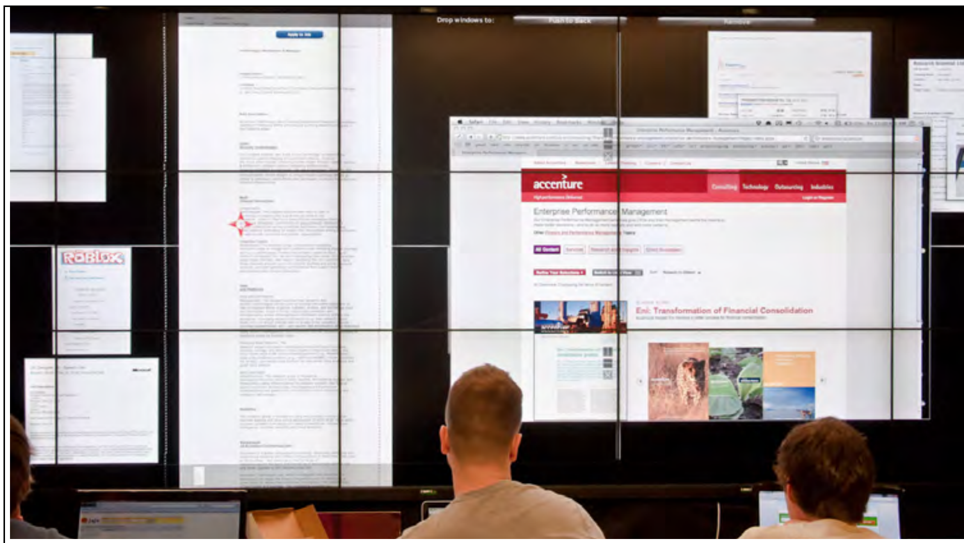
- How is the display space organized when the work is divided among users (i.e., when they work separately)?
- How is the display space organized when users work together to reach an agreement?
- What do the group dynamics look like in display wall environments?
- How do users coordinate input control, and which modes of interaction are used?
- What are the fundamental window organization techniques employed during the study?
- How can we design display wall spaces that facilitate collaborative work and help users better manage large amounts of information?

Part One – Individual Web Searching and Data Gathering

Sections explicitly defined personal workspaces and allowed participants to employ individual organization strategies.

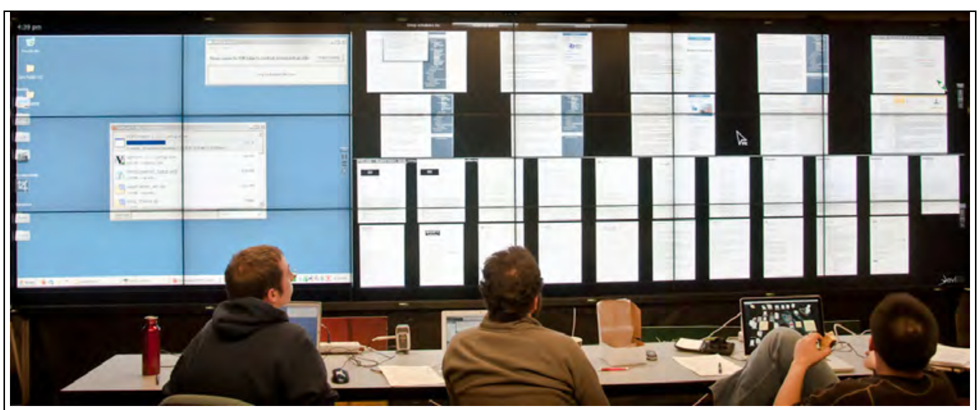
Implicitly defined personal workspaces loosely correspond to users' seating positions, require more physical distance for clarity, and necessitate manual window organization.

Part Two – Collaborative Analysis and Filtering



Typical window layout during filtering stage consisted of the job posting and the supporting information in focus on top of the structured layout underneath.

Fundamental Organization Techniques



To get around the limitation of the automatic tiling algorithm and maximize space usage, users would sometimes group windows of similar aspect ratios into separate sections.

Physical navigation proved more natural and required minimal window manipulations.

2.A.11. SAGE and Audio

This year, EVL began working with the Calit2/UCSD Sonic Arts Group to develop a robust audio system for SAGE, referred to as SAM (SAGE Audio Manager). The goal is to have SAGE treat audio as sample buffers the same way it treats video as pixel buffers. There are four use cases for SAGE audio:

- *Audio streamed from a laptop or other device to the SAGE wall* (Must use WIFI; must operate on Macs, Windows, Linux laptops; must accommodate several streams to the wall simultaneously; and, must deal with buffering issues)
- *Audio playback from within SAGE* (This can be applications within SAGE or media pushed to the wall.)
- *External device connected to SAGE wall* (Microphone, LifeSize, JPEG2000 codec (via disembedder), etc.; might require echo cancellation.)
- *Connecting two SAGE walls via network* (For simultaneous playback of audio; does not need WIFI).

2.A.12. Voice Command

A much less examined modality for interacting with tiled display walls is voice commands. Voice commands are most effective when recognition accuracy is high, when they do not require the user to memorize a vocabulary or grammar, and when it takes less time to utter the verbal command than to perform the action through direct manipulation. EVL is currently developing *Articulate,* a system that attempts to interpret natural language queries to automatically produce appropriate visualizations of data. Though not yet embedded into SAGE, *Articulate* is compelling for controlling tiled display walls because it can provide a rapid means of creating data plots and other more advanced visualizations without requiring the user to struggle with yet another user-interaction device. The use of a natural language interpreter enables the user to issue commands without conforming to a rigid grammatical structure, and a graph reasoner enables the system to make an educated guess as to the type of visualization that best answers the user's query. The approach de-emphasizes the physical manipulations needed to create a desired graph so that the user can focus on asking questions about the data. Initial studies of the system show this indeed to be true. Users took less time to accurately produce a desired graph using Articulate than a more familiar tool, Microsoft Excel.

2.A.13. SAGE-Next

EVL is currently developing the next-generation SAGE, to take advantage of many lessons learned since EVL began developing SAGE in 2002, and to take advantage of the newest computer architectures and cloud computing. SAGE-Next will be backward compatible with SAGE.

Currently, one PhD student is working on a multi-user-centric resource scheduler for SAGE-Next.

SAGE's uniqueness is that it supports distance collaboration among multiple endpoints equipped with tiled display walls connected via high-speed networks. It enables users to simultaneously share ultra-high-resolution scientific visualizations with remote collaborators while communicating with them via multi-point high-definition video and audio streamed to the displays.

Historically, computer clusters are used to drive tiled display walls. With the advent of "multi-headed" graphics cards, such as AMD's Eyefinity, Nvidia's Scalable Visualization Solutions, and Matrox's Display Wall Controller, it is possible to support over a dozen displays from a single PC. Driving a tiled display with a single computer greatly reduces the cost of ownership and maintenance of a tiled display wall. Furthermore it enables applications to run natively thereby eliminating the need to parallelize them. On the other hand, driving a high-resolution wall with a single computer introduces significant challenges in resource management. In particular, the operating system must be able to intelligently align the cores of a CPU, the available network capacity, bus bandwidth, and GPU resources to respond to the real-time interactions of multiple users attempting to manipulate content on the wall at the same time.

Traditional resource scheduling in modern operating systems that focus on fair sharing of resources and system-wide job completion throughput can fail to provide perceived good performance, expected by users, when the system is overloaded. Also, hierarchical memory architecture in modern multi-core processors is not efficiently utilized by operating systems. For SAGE, the prioritization of system resources is not necessarily based on fastest job completion time, such as in traditional approaches, but rather, which windows are the largest on the wall, which ones are least occluded by other windows, and which ones are interacting with a user. Work to develop a multi-user interaction-based resource manager is currently underway in the design of the next generation of SAGE, called *SAGE-Next*. To adequately control system resources, SAGE-Next uses the concept of Rails, which enables the alignment of specific cores and memory caches of a CPU, system interrupts, and network interfaces, on an application basis – in essence providing applications with the notion of "Quality of Service".

SAGE-Next supports multi-user collaborations of multiple content, and provides a plugin interface for application developers to develop cloud applications. SAGE-Next maintains compatibility with SAGE, so that it will support streaming of images from SAGE applications as well as allowing tiled walls to be the visualization endpoint of cloud technology.

2.A.14. Education, Outreach and Broader Participation

2.A.14.1. SAGE Press Releases and Videos

SAGE and the Cyber-Commons tiled display wall have appeared in the news and on YouTube.

SIGGRAPH conference animates Vancouver, Vancouver Sun, Business section, August 10, 2011, <http://www.vancouversun.com/business/Videos+SIGGRAPH+conference+animates+Vancouver/5237520/story.html>; Photos: <http://www.vancouversun.com/business/Photos+Siggraph+Convention/5229671/story.html>. NOTE: The Vancouver Sun has photos of SIGGRAPH 2011 attendees interacting with both SAGE and other EVL touch-screen applications. Although the credits are incorrect, the fact that this technology was featured (out of the 100s or 1000s of technologies shown at SIGGRAPH), is a feat in itself.

Fleet Commander (video), YouTube, July 2011, <www.youtube.com/evltube#p/a/u/0/6V0o3TjB2Tw>

Introduction to the Electronic Visualization Laboratory @ UIC (video), YouTube, May 25, 2011, <www.youtube.com/evltube#p/a/u/1/4VdBnH9_47E>

Kinect for SAGE (video), YouTube, May 24, 2011, <http://www.youtube.com/evltube#p/a/u/2/oFQeszkCaPU>

Diamonds in the digital rough - female computer scientists shine, Medill School of Journalism, Northwestern University, May 18, 2011,

<http://news.medill.northwestern.edu/chicago/news.aspx?id=186381>

UIC Public Service Announcement Featuring EVL (video), YouTube, April 28, 2011, <http://www.youtube.com/user/evltube?feature=mhum#p/a/u/0/c-1gdRLLgvQ>

Supercomputers Are the New Microscope, Gizmodo, April 26, 2011, <http://gizmodo.com/#!5795725/supercomputers-are-the-new-microscope>

Digging Deeper, Seeing Farther: Supercomputers Alter Science, New York Times, April 25, 2011, <http://www.nytimes.com/2011/04/26/science/26planetarium.html?_r=2>

US-Japan Continues Formal Collaboration, EVL News, April 25, 2011, <http://www.evl.uic.edu/core.php?mod=4&type=4&indi=754>

Science Can Be Beautiful: UIC Image of Research 2011, UIC News, April 13, 2011, <http://www.uic.edu/htbin/cgiwrap/bin/uicnews/articledetail.cgi?id=15240>. NOTE: EVL students JD Pirtle, Arthur Nishimoto, Karan Chakrapani, Todd Silvia, and Philip Pilosi, who represent undergraduate and graduate students in both computer science and new media arts, received Honorable Mention for "20 Foot Canvas." EVL student Ed Kahler, a computer science graduate student, was a Finalist for "Cli-Mate," an interactive application that allows climate scientists to view and analyze their data in a multi-touch environment.

OptIPortables Bring High-Tech Collaboration to San Diego Communities, Calit2, March 7, 2011, <http://www.calit2.net/newsroom/article.php?id=1808>

CineGrid Receives 2011 CENIC Innovations in Networking Award, CineGrid, March 7, 2011, <www.cinegrid.org/index.php?option=com_content&view=article&id=145:cinegrid-receives-2011-cenic-innovations-in-networking-award&catid=1&Itemid=11>

Cyberspace wall connects global real-time imaging, Northwest Indiana Times, February 27, 2011, <http://www.nwitimes.com/business/local/article_923b3ced-98b4-5132-9a2a-7255b92287c9.html>

Cyberspace wall connects real-time global imaging, conferencing, data, Medill Reports Chicago, Northwestern University, February 22, 2011, <http://news.medill.northwestern.edu/chicago/news.aspx?id=179303>

PBS to feature UIC professor's pioneering avatar research (Blog of University of Illinois President), January 21, 2011, <http://prezrelease.uillinois.edu/2011/01/21/avatar-research/>

Can we live forever? (video – profile of Jason Leigh), Nova ScienceNOW, January 26, 2011, <http://www.pbs.org/wgbh/nova/tech/jason-leigh-avatars.html>

Scalable Adaptive Graphics Environment (SAGE) 2010 (video), YouTube, January 6, 2011, <http://www.youtube.com/evltube#p/u/5/Pd0jQAHEIc8 >

When art meets science, there's no time to watch the paint dry, UIC News, December 1, 2010, <www.uic.edu/htbin/cgiwrap/bin/uicnews/articledetail.cgi?id=14854>

SAGEBridge, AARNews, December 2010, <http://www.aarnet.edu.au/library/AARNews_Issue19.pdf>

20 Foot Canvas (video), YouTube, November 2010, <www.youtube.com/evltube#p/a/u/0/lq6ShJnwr1Y>

Multi-Modal Multi-User Interaction in SAGE (video), YouTube, November 2010, <www.youtube.com/evltube#p/a/u/1/LlERXh5iin0>

UIC researchers paint on 20-foot electronic canvas, Chicago Journal, November 10, 2010, <www.chicagojournal.com/News/11-10-2010/UIC_researchers_paint_on_20-foot_electronic_canvas>

18-screen digital paint wall supports touch, iPad doodling (video), Engadget, November 9, 2010, <www.engadget.com/2010/11/09/18-screen-digital-paint-wall-supports-touch-ipad-doodling-vide/>

Researchers paint on 20-foot electronic canvas, Medill School of Journalism, Northwestern University, November 4, 2010, <http://news.medill.northwestern.edu/chicago/news.aspx?id=171884>

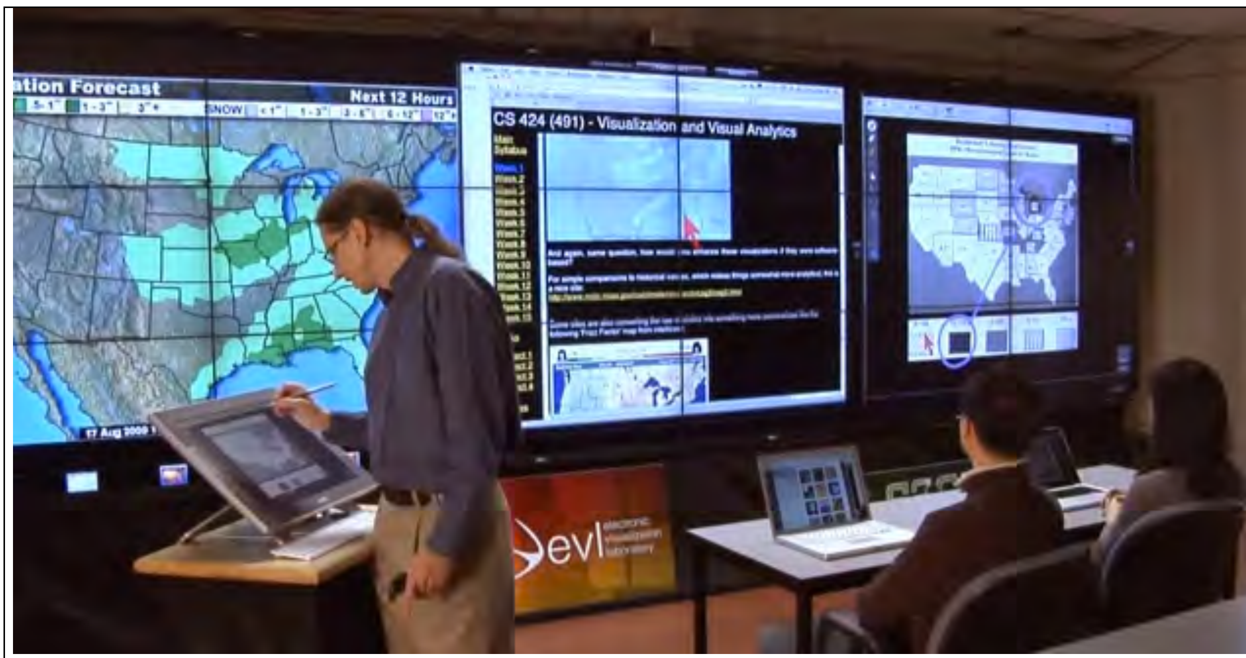
Articulate: a Conversational Interface for Visual Analytics (video), YouTube, June 21, 2010 <http://www.youtube.com/evltube#p/u/12/V1CFRv4Q8bk>

2.A.14.2. SAGE in the Classroom: Cyber-Commons

Cyber-Commons is a technology-enhanced meeting room on the UIC campus that supports local and distance collaboration and promotes group-oriented problem solving in formal and informal situations. More specifically, Cyber-Commons is a large-scale tiled display wall with 20Gbps of networking that runs SAGE, though SAGE is not required for its use.

EVL supports and uses Cyber-Commons for classroom instruction for undergraduate, Masters and PhD students. Cyber-Commons' goal is to help students learn how to collaborate within a university and among universities – to solve problems within a discipline and among multiple disciplines. The components of Cyber-Commons can be altered and enhanced as needed to build the right-sized space with the right amount of local computing power and the right amount of networking to match local needs.

SAGE enables multiple users to simultaneously interact with the wall by touching it (enabled by the touch screen overlay) to move windows, add content from a media library, or organize content. Other users can simultaneously drag and drop content onto the wall from their laptop, or control remote pointers on the wall. Others can draw on a Wacom tablet that is streamed to the screen as a blackboard (illustrated below). Content includes image files, movie files, Microsoft Office files, and streaming desktops through VNC. Groups can form and re-form on the wall and divide the wall space up among multiple concurrent tasks. The current state of the wall can be saved, and older states can be re-loaded at later times.



Professor Andy Johnson using the Wacom tablet to annotate the rightmost image on the Cyber-Commons 18-Megapixel tiled display wall. From the YouTube EVL video "Scalable Adaptive Graphics Environment (SAGE) 2010" <www.youtube.com/evltube#p/u/5/Pd0jQAHEIc8>.

Since the summer of 2009, when the Cyber-Commons wall was installed, 12 different UIC courses have been taught by six different instructors in the new Cyber-Commons: CS 340 Software Design; CS 376 Practicum in Computer Science Presentations; CS 426 Video Game Design and Programming, with half of the class *virtually* attending from Louisiana State; CS 424 Visualization and Visual Analytics; CS 524 Visualization and Visual Analytics II; CS 525 GPU Programming; CS 527 Computer Animation; CS

528 Virtual Reality; CS 594 Computational Biology, with a live link to Princeton; Physics 594 Parts 1 and 2 - Hunt for the Quark Gluon Plasma, with remote lectures from Los Alamos and CERN; and Art and Design 508 Advanced Electronic Visualization and Critique. There are also regularly scheduled research meetings, seminars, and videoconference calls that take place in Cyber-Commons several times a week.

We have also seen and encouraged ad-hoc use of the Cyber-Commons outside of regularly scheduled classes and meetings. Groups of students in the Visual Analytics course and the Video Game Design course use the space to brainstorm different ideas using the Wacom tablet on the wall as a whiteboard. Groups of graduate students discuss ideas for their research and upload related journal papers onto the wall from their laptops. Groups of PhD students studying for the qualifying exam display multiple exams and their answers along with related web pages on the wall for discussion.

Since 2010, EVL has been advising KISTI (Korean Institute of Science and Technology Information), who is collaborating with Seoul National University with funding by the Korean Ministry of Education, Science, and Technology, on how to deploy 40 networked tiled display walls based on our Cyber-Commons model around Korea in the next three years, with seven to be deployed in 2011.

Thus far, tiled display walls primarily display 2D content. With the advent of 3D-capable LCD displays it is likely that all future displays will provide such a capability essentially for free, in the same way that stereo and surround-sound audio are standard features of all audio/visual systems today. In the early 90s, stereoscopic head-mounted displays and immersive CAVEs cost between tens of thousands of dollars to a million dollars; today, a 3D television costs as little as a thousand dollars.

EVL recently dismantled the current Cyber-Commons tiled display wall and, with other funding, is replacing it with 3D passive-stereo displays, as well as building a separate 3D passive-stereo 2x2 tiled display wall for SAGE development and prototyping. Because the power supplies of the new displays are not attached to the back of the LCDs, we can remote them and the computer cluster that drives the system (which helps dissipate both heat and noise). Electricians are currently mounting equipment cabinets and electrical service outside the Cyber-Commons room to accommodate.

2.A.14.3. SAGE Technical Demonstrations and Presentations

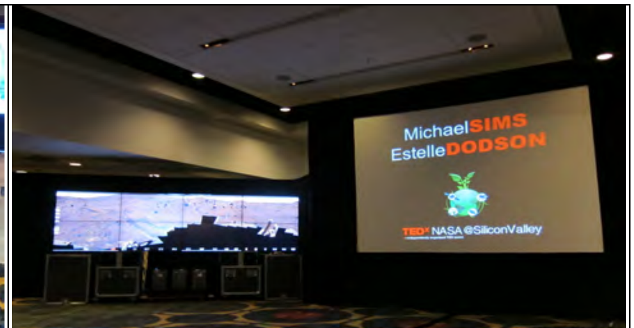
Upcoming: EVL is working with Ciena Networks on SAGE trials between Chicago and Ottawa as part of the company's Future Internet and emerging immersive media environments demonstrations (September 26 – October 28, 2011); has provided technical support to Extreme Networks for SAGE demos at Interops (October 3-7, 2011, Las Vegas); and, is talking with Swedish, Australian and Japanese colleagues who have expressed interest in doing demonstrations at the 7th annual IEEE e-Science conference (December 5-8, 2011, Stockholm, Sweden).

August 24-26, 2011. EVL PhD student Sungwon Nam traveled to Monsanto in St. Louis, MO, to install SAGE on their nanoWall, a 2x2 NEC 46" tiled display wall, and to train their technical staff.

August 17, 2011. EVL graduate Ratko Jagodic participated in TEDxNASA@Silicon Valley in San Francisco <http://tedxnasa.com/silicon-valley/>. TED stands for Technology Entertainment Design, and "x" means it is an independently organized TED event. NASA colleagues Estelle Dodson and Michael Sims gave a talk on "Walls without borders" while Jon Welch demonstrated SAGE running on NASA's OptIPortable. The audience of 500+ people asked many questions. Jagodic video'ed the SAGE portion of the presentation and uploaded to YouTube; see <http://www.youtube.com/watch?v=RgU5_x9-kos>.

August 15-16, 2011. EVL graduate Ratko Jagodic, who developed the SAGE User Interface, gave the presentation "Data Visualization and High Speed Research Networks for Space Exploration," at the NASA IT Summit 2011 in San Francisco <http://www.nasa.gov/offices/ocio/itsummit/index.html>. NASA Ames, now a SAGE user, also did SAGE demonstrations. In an email about his experiences, Jagodic wrote, "There were a lot of video walls there and the attendees thought the OptIPortable was just another one of those...until we stepped up to them and started interacting, which immediately set it apart and the implications became obvious to just about everyone. Then I gave a talk…about the 'future,' or how they could work given EVL's tech…People loved my part and most of them afterwards came by the booth to see it in action and were equally impressed and grabbed some SAGE handouts."

NASA IT Summit 2011 and OptIPortable/SAGE demo. Photo: Ratko Jagodic.

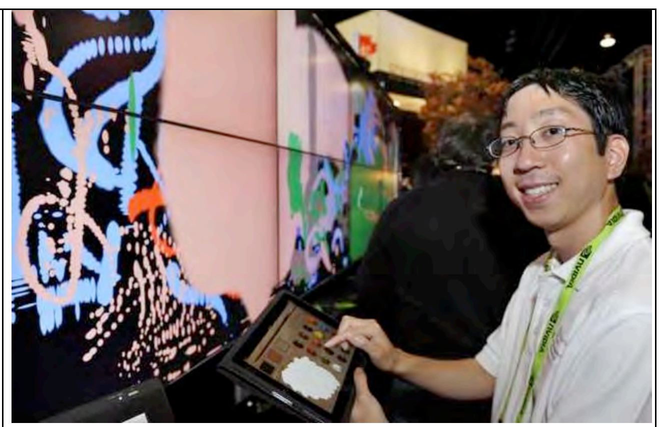


TEDxNASA@Silicon Valley 2011 and OptIPortable running SAGE (on left of screen). Photo: Ratko Jagodic.

August 15-17, 2011. Jason Leigh gave the keynote "Global Cyber-Commons: Supporting Global Collaborative Research, Development, and Education in Cyber-Infrastructure-Enhanced Environments" at the American-Chinese Cyberinfrastructure and E-Science workShop (ACCESS) 2011, the third of a series of workshops that bring together researchers, educators, users, and practitioners of cyberinfrastructure and e-Science in China and the U.S. <http://access11.cnic.cn/dct/page/1>. ACCESS is co-organized by the Computer Network Information Center (CNIC) of the Chinese Academy of Sciences and the National Center of Supercomputing Applications (NCSA) at University of Illinois at Urbana-Champaign, and held in Xi'an, China. The theme of this year's annual event was VIsualization and Visual Analytics (VIVA).

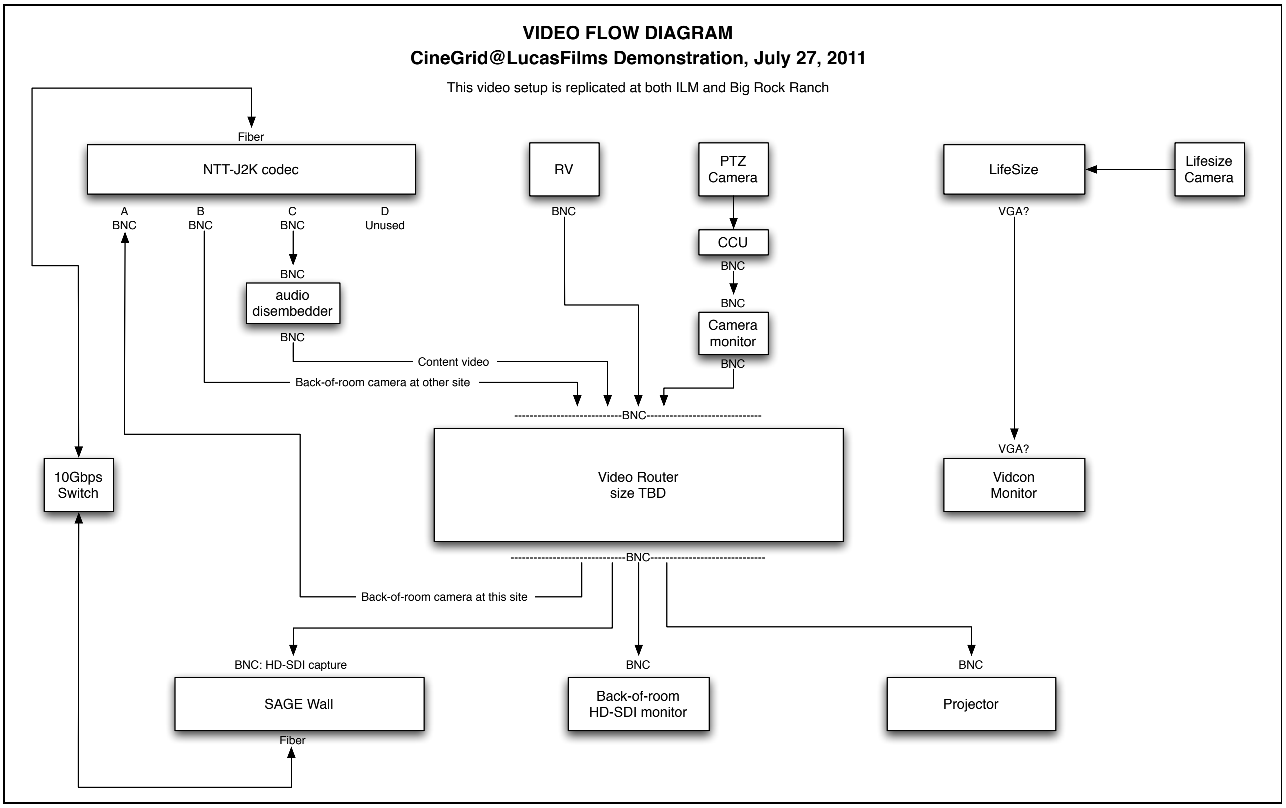
August 9-11, 2011. Luc Renambot, Arthur Nishimoto and Khairi Reda of EVL gave demonstrations with partner Calit2/UCSD in the KAUST booth at ACM SIGGRAPH 2011 in Vancouver, Canada. Two of Calit2's *OptIPortables* were connected to form a 2x4 wall equipped with a touch screen in order to run EVL SAGE software as well as other applications, such as EVL's Paint Program. EVL demos were a big sensation and highlighted in the Business section of the *Vancouver Sun* newspaper, although they were inaccurately attributed to other institutions. *Vancouver Sun* story: <http://www.vancouversun.com/business/Videos+SIGGRAPH+conference+animates+Vancouver/5237520/story.html>; *Vancouver Sun* photos: <http://www.vancouversun.com/business/Photos+Siggraph+Convention/5229671/story.html>.

SIGGRAPH 2011 attendee moves SAGE windows around on OptIPortable system with touch screen in the KAUST booth. (Photo: Tom DeFanti)


Arthur Nishimoto, EVL, demonstrates EVL's paint system on the OptIPortable system with touch screen (does not use SAGE). The iPad is used as a palette, allowing users to mix colors and select brush styles. (Photo: Vancouver Sun)

July 27, 2011. Along with CineGrid members Calit2, NTT Network Innovation Laboratories and Pacific

Interface, EVL did SAGE remote collaboration demonstrations for Lucasfilm/ILM. Two OptIPortables, provided by Calit2, were set up in the main theater of Lucasfilm's Presidio location (San Francisco) and in the main theater of their Big Rock Ranch (Marin County). EVL's Jason Leigh, Luc Renambot and Arthur Nishimoto were at the Presidio and Ratko Jagodic was at Big Rock Ranch. A diagram of the video setup is below. *Note: This information is CONFIDENTIAL and not for public distribution.*



July 5-9, 2011. EVL graduate student Arthur Nishimoto visited Calit2 to install the necessary software to interface a PQ Labs touch screen to an OptIPortable system. SAGE, as well as several non-SAGE applications developed by EVL (Paint System, Fleet Commander videogame) utilize the touch screen.

July 1, 2011. Ratko Jagodic, EVL graduate student, successfully defended his PhD dissertation, entitled *Collaborative Interaction and Display Space Organization in Large High-Resolution Environments.* Jagodic designed and developed the SAGE User Interface.

June 28, 2011. Collaborators from the University of Chicago's NHP (New Hospital Pavilion) Planning Committee visited EVL to discuss the viability of creating an Operating Room of the future and installing a tiled display running SAGE. Their goal is to have a "wall of knowledge" (WOK) where live streams, patient radiology, 3D volume-rendering client patient scans, etc. can be flexibly displayed.

June 24, 2011. EVL partner TACC (Texas Advanced Computing Center) held its 10th Anniversary Celebration and Colloquium, featured tours of its Visualization & Science Gallery, where they use SAGE.

June 16, 2011. Ben Fineman and Mike LaHaye of Internet2 visited EVL to learn more about SAGE and OptIPortables for multi-site collaboration.

June 13, 2011. Jason Leigh gave a presentation at the International Society of the Arts, Mathematics, and Architecture conference (ISAMA 2011) held at Columbia College, Chicago <www.isama.org>.

June 10, 2011. Roger Ady, Director of Engineering for Mobile Devices of Motorola, toured EVL.

June 8, 2011. EVL participated in a VTC with partners at Calit2/UCSD and the Navy Postgraduate

School. EVL spoke with Dr. Jack Thorpe about using SAGE and OptIPortables for Remote Collaboration for Humanitarian Assistance / Disaster Recovery.

June 3, 2011. Several people from Monsanto headquarters in St. Louis – Michelle Weber, Barry Goldman, David Bush and Jeff Woessner – visited EVL to learn more about SAGE, tiled displays, and 3D passive stereo displays.

May 23-24, 2011. Andy Johnson gave the invited talk "Cyber-Commons – a high resolution, high bandwidth, collaborative environment for managing scale and complexity," at the Next Generation Imaging Workshop, Lincoln Imaging Sciences Center (LISC), Dedham, MA, sponsored by MIT Lincoln Labs.

May 16-29, 2011. Jason Leigh and Luc Renambot of EVL visited KAUST (King Abdullah University for Science and Technology) in Saudi Arabia. EVL receives KAUST funding to develop and deploy some of its visualization technologies; KAUST is most interested in SAGE as a tool for distributed, collaborative research over high-speed networks with funded groups in the US and elsewhere. Renambot created and installed a SAGE binary package for "Scientific Linux 6," a Linux distribution that KAUST is evaluating for its visualization infrastructure; worked on triggering audio events in SAGE; and, worked to get a stable SAGE install for KAUST students to use. Leigh gave several overview presentations on EVL's research and had discussions with KAUST VisLab management. Both Renambot and Leigh gave presentations on the SAGE roadmap followed by discussions of development priorities for Year 3 of the NSF SAGE award.

	
Jason Leigh in the KAUST Visualization Laboratory Showcase. (Photo: Luc Renambot)	Jason Leigh giving an EVL overview presentation at KAUST. (Photo: Luc Renambot)

May 16, 2011. Seok-Myun Kwon and Jin Kim of KISTI (Korea) visited EVL for the day to learn more about SAGE user interface development, as KISTI wants to standardize on SAGE and tiled display walls for distributed, collaborative research and education. In Korea, they have OptIPortal-like collaboration facilities at KISTI and six national universities that are used for remote education. They want to better understand SAGE to see if they can modify it for their educational requirements.

May 13, 2011. Calit2/UCSD built and deployed two SAGE OptIPortables to community centers in the San Diego area – to South Metro Career Center (SMCC) in San Diego's Mount Hope community and to Casa Familiar in San Ysidro. They previously trained the staff and students who work/visit the center to use SAGE. (EVL provided technical support.)

April 19-25, 2011. Luc Renambot visited the University of Hawaii at Manoa's Center for Microbial Oceanography: Research and Education (C-MORE) to assist with SAGE installation and training on two OptIPortals.

April 13-15, 2011. Sukumar Srinivas and Joe Keefe of Calit2 did SAGE demonstrations at the 3rd annual site visit of the NSF ERC Center for Integrated Access Networks (CIAN) at University of Arizona. EVL's Maxine Brown and Luc Renambot provided presentation materials.

April 11-14, 2011. Two EVL graduate students, Mike Lewis and Huy Bui, who are interested in how SAGE can be integrated with cloud computing, attended several workshops hosted at Argonne National Laboratory: GlobusWORLD (April 11-12); CCA11, Cloud Computing and Its Applications (April 13); and the Workshop on Applications for Clouds (April 14).

April 4, 2011. EVL gave a tour to Madam Kawther Al Abood, who is affiliated with MIT Media Lab.

March 10, 2011. Jason Leigh gave a SAGE presentation at MIT Lincoln Labs.

March 9-25, 2011. Tom DeFanti, Calit2/UCSD, was in Australia and Singapore, and gave a number of presentations promoting SAGE.

March 7, 2011. Drs. Paul Walsh and Roy Sleator of the Cork Institute of Technology in Cork, Ireland, visited EVL to learn about its technologies.

March 1-4, 2011. The 10th Annual ON*VECTOR International Photonics Workshop was held at Calit2/UCSD. EVL's Luc Renambot gave the presentation "SAGE/iVisto Integration Experiment: SAGE Application Perspective" and worked with NTT on real-time SAGE demonstrations of both iVisto (video streaming) and Robust Media Search (digital fingerprinting). This demo was also done for the NTT-sponsored Digital Media Analysis, Search and Management (DMASM 2011) Workshop held earlier in the week.


SAGE/iVisto integration demonstration.

February 21, 2011. Jason Leigh gave the presentation "Global Cyber-Commons: Supporting Global Collaborative Research, Development, and Education in Cyber-Infrastructure-Enhanced Environments" at Michigan Technological University.

February 7, 2011. Disney executives visited Calit2 to learn about SAGE and tiled display walls. EVL did a remote demo with Calit2.

January 14, 2011. Tom DeFanti participated in a panel on wired broadband futures and GLIF international networking, particularly with respect to Australia's AARNet, for the Australian American Leadership Dialogue (AALD) delegation meeting at Calit2. AALD is a group of Australian government, business and academic leaders who have worked at the highest levels with their US counterparts for 20 years. Luc Renambot (EVL) demonstrated SAGE between two OptIPortals in Chicago/EVL and San Diego/Calit2.


SAGE demonstration to AALD delegates.

January 10, 2011. Calit2 had 30 visitors from the Harvard Business School. During site tours, Tom DeFanti did a collaborative SAGE demonstration between Calit2 and EVL.

January 6, 2011. Larry Smarr, Calit2, was a Distinguished Lecturer for the Hawaii International Conference on System Sciences (HICSS-44) in Kauai, HI. He gave the presentation "Building a Global Collaboration System for Data-Intensive Discovery" and talked about SAGE, OptIPortals and international collaboration.

December 13, 2010. Instituto Tecnologico de Costa Rica (ITCR) became a PRAGMA member and contacted other PRAGMA members about using OptIPortals/SAGE to collaborate on metagenomics. While UIC/EVL does not do metagenomics, we offered some alternatives. Ideas are still pending.

December 12-15, 2010. EVL participated in the annual CineGrid workshop. Luc Renambot gave a presentation on "SAGE OptIPortable with iVisto for Collaboration" and conducted several SAGE demonstrations between EVL and Calit2/UCSD. Jason Leigh gave the presentation "Big Picture Collaboration Using SAGE OptIPortals," and Alan Verlo spoke about "Networking for Collaboration."

December 7-10, 2010. The IEEE e-Science 2010 conference was held at Queensland University of Technology (QUT) in Brisbane, Australia. University of Queensland did SAGE demos on OptIPortals at QUT that were Visualcasted to AARNet in Sydney.

 Professor Bernard Pailthorpe of University of Queensland, at the conference site, being Visualcasted to remote sites.	 Chris Willing, AARNet, demonstrates Paraview rendering a model in MPI-mode across the OptIPortal cluster and then output via SAGE.

University of Queensland ran Paraview in MPI-mode across AARNet's OptIPortal cluster. University of Queensland also conducted *Tiled Display Wall* workshops, designed for both new users as well as researchers already operating tiled display walls. Current and future applications of display wall technology were discussed, including the role of SAGEBridge (for Visualcasting), and opportunities for participants to collaborate and contribute to a growing community.

The AARNet November 2010 newsletter reported that the use of OptIPortal visualization walls among Australian institutions has grown to a level where interaction beyond the usual point-to-point has become feasible, and has opened up opportunities for multi-site collaborations. EVL's SAGE is gaining broad acceptance in serving this purpose. Various VisCasting sessions were conducted among SAGE-enabled OptIPortals, particularly among AARNet (Sydney), University of Queensland and NICT in Japan, generating up to 7Gbps across the network, and over 10Gbps in the lab! See <http://www.aarnet.edu.au/library/AARNews_Issue19.pdf>.

December 6-17, 2010. Tom DeFanti had visitors from Petrobras, a Brazilian oil conglomerate, and their Brazilian university partners, who are charged with building a networked visualization center. They visited Calit2 to learn what to do. They also attended the CineGrid Workshop. Luc Renambot met with them December 9-10 to talk about SAGE and how it enables video streaming over international high-performance networks. Alan Verlo met with them to talk about StarLight, GLIF and our collaborations with RNP in Brazil. DeFanti covered such topics as building NexCAVEs, OptIPortables, SAGE, and the CineGrid Exchange. The visitors were: Luciano Pereira Dos Reis, Technical Consultant, Reservoir Geological Engineering, Petroleo Brasilia, S.A., Mario Pimenta, responsible for the IT issues related to the Visualization Center at Petrobras, and from Pontifícia Universidade Católica (PUC), Alberto Raposo, the manager of the VR team, and Thiago Bastos Tecgraf/PUC-Rio (Pontifícia Universidade Católica).

November 30, 2010. Maxine Brown visited the NOAA Great Lakes Environmental Research Laboratory (GLERL) and Great Lakes Observing System (GLOS), headquartered in Ann Arbor, and gave presentations on EVL and the Great Lakes Consortium for Petascale Computation (GLCPC). Several individuals from UIUC and NCSA also attended and talked about possible collaboration on a "Digital Great Lakes" project.

November 29, 2010. Moon-Ho Park, Senior engineer at Samsung Electronics, visited EVL and spoke with Andy Johnson regarding possible technical transfer solutions.

November 15-18, 2010. EVL participated in the SC10 conference. EVL organizing a successful SAGE Birds-of-a-Feather on Tuesday, November 16, did SAGE demos in the KAUST booth, and assisted SAGE users at SC10 with their demos.


SC10 SAGE BOF attendees.


SAGE demo in the KAUST booth.

SAGE demo in the KAUST booth.

October 20, 2010. Luc Renambot and Jason Leigh gave a half-hour remote VTC presentation on SAGE to people at the PRAC Workshop at the National Center for Supercomputing Applications (NCSA).

October 13-14, 2010. EVL participated in the GLIF 10th Annual Global LambdaGrid Workshop, held at CERN in Geneva, Switzerland. Maxine Brown is co-chair of the GLIF Research & Applications Working Group, and as part of her session, Tom DeFanti gave the presentation "TransLight/StarLight: The Lightpath is not the Goal, the GOLE is the Goal." SAGE was one of several international application and middleware experiments mentioned in his presentation.

Also during the GLIF Workshop, SARA's Network Research Group streamed ultra-high-resolution scientific visualization animations over a SURFnet 40Gbps lightpath between SARA in Amsterdam and CERN in Geneva. They repeated this demo at the SC10 conference (New Orleans) in November, streaming locally within their booth.

EVL put considerable time into working with SARA colleagues to trouble shoot issues encountered with SAGE; however, bottlenecks could not be resolved and ultimately SAGE was not used. We include this demo here because it provided a rich proving ground to analyze SAGE capabilities, as explained below.

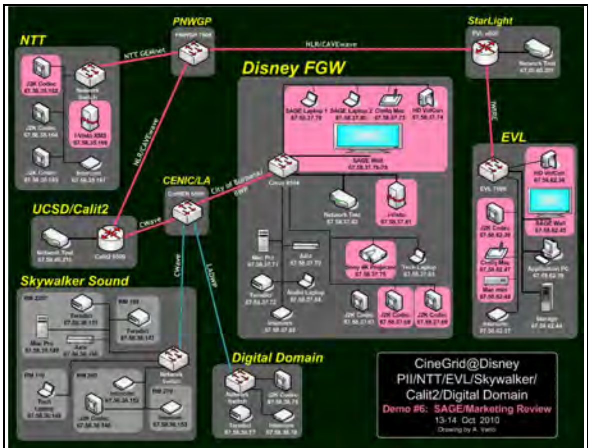

SARA's streaming demo at GLIF 2010.

Tijs de Kler of the SARA Visualization Group wrote a thoughtful analysis of why SAGE failed. Essentially, the research problem they wanted to solve was doing 40Gbps from a single machine and disk; i.e., there was significant I/O from disk to memory to network, all from one machine.

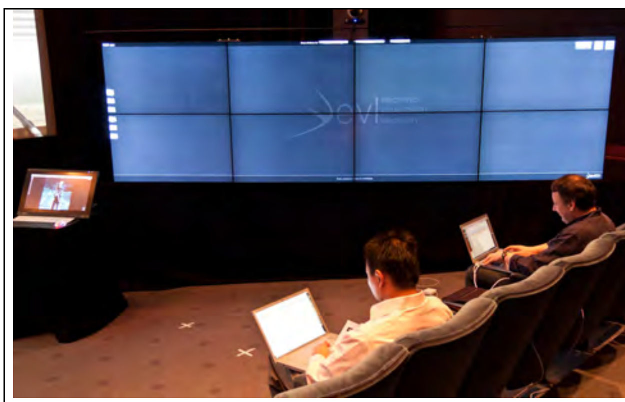
The way SAGE streams data is to first read it into a buffer, and then hand it off to networking threads. Here, the data is divided into blocks, and streamed to receiving nodes with a header attached to identify what block it is. Streaming is done dynamically, with SAGE determining what blocks go to what receiving nodes and, if necessary, to multiple nodes if the image falls across a border. In SARA's case, SAGE streaming didn't scale well. It couldn't get past the 16Gbps mark, and was mainly running out of CPU. However, *netperf* showed that higher speeds (up to 39.6Gbps) could be reached with a fraction of the CPU used.

Additional benchmarking with a simple application, doing nothing more that reading data from a file and sending it over a UDP socket, showed similar bottlenecks. But, if either disk reading or network streaming was taken out, it did fine. The conclusion was that moving data from disk to user space memory, and back to the network was the problem, requiring too much of the CPU. SARA then came up with a solution that would do it more efficiently. While their solution is unwieldy and not general purpose (like SAGE), it works for this demo.

October 11-14, 2010. EVL, along with Calit2, NTT Network Innovation Laboratories and Pacific Interface Inc. (who are all members of the CineGrid organization), organized a demo for Disney Studios, for an internal audience of 100. The CineGrid@Disney demonstration represented the first prototype of a *next-generation, multi-function, networked, remote collaboration facility for globally distributed cinema post-production and marketing.* Specific use cases demonstrated included: 4K/60p telepresence virtual conference room; critical viewing of digitally restored archival film elements at 4K and 2K resolutions streaming from a remote server; Digital Intermediate (DI) color grading; critical viewing of 3D high-definition stereoscopic visual effects; collaborative audio editing and mixing; and, use of EVL's SAGE software and multi-panel display walls for collaborative review of multimedia marketing materials. Specifically, participants shared and discussed marketing materials for the new *TRON Legacy* movie. While most use cases involved point-to-point bilateral collaboration, several required triangular collaboration configurations using multicasting. The network configuration for the SAGE collaboration workflow demo appears above.



CineGrid@Disney network configuration for SAGE demonstrations.



EVL's Luc Renambot, Jason Leigh and Ratko Jagodic prepare for the CineGrid@Disney SAGE demo. (Photo: Ratko Jagodic)

Some of those participating in the event were (left to right: Leon Silverman, General Manager of Digital Studio Operations, Walt Disney Studios; Mark Harrah, Executive Director, Post Production, Walt Disney Studios; Jeff Schectman, Senior Vice President of Creative Film Services, Walt Disney Studios; Jason Leigh, EVL; Andy Fowler, Vice President and Senior Visual Effects Producer, Walt Disney Studios; Sara Duran-Singer, Senior Vice President of Worldwide Post Production, Walt Disney Studios; Laurin Herr, President, Pacific Interface Inc.; Phil Benson; Executive, Skywalker Sound, a Lucasfilm Company. (Photo courtesy of Pacific Interface, Inc.)

The CineGrid@Disney demo received the CENIC (Corporation for Education Network Initiatives in

California) 2011 Innovations in Networking Award, in the Experimental/Developmental Applications category. The award was presented at the 2011 CENIC Annual Conference, held March 7-9, 2011 at UC Irvine. <www.cinegrid.org/index.php?option=com_content&view=article&id=145:cinegrid-receives-2011-cenic-innovations-in-networking-award&catid=1&Itemid=11>.

September 14, 2010. Larry Smarr visited the NSF Science & Technology Center for Microbial Oceanography: Research and Education (C-MORE) at University of Hawaii, where they expressed interest in being more aggressive SAGE users and using SAGE to better collaborate with C-MORE partners at MIT and University of Washington.

2.A.14.4. SAGE Outreach

EVL does numerous education and outreach demonstrations to assist UIC with recruitment, retention, and professional development efforts. EVL faculty and students both demonstrate SAGE and use SAGE to give EVL overview presentations in the Cyber-Commons room.

EVL's Andy Johnson uses SAGE to give most of the Lab's overview presentations to UIC visitors and prospective students. This image is from the YouTube video "Introduction to the Electronic Visualization Laboratory @ UIC" <www.youtube.com/evltube#p/a/u/1/4VdBnH9_47E>.

August 17, 2011. EVL research associate JD Pirtle and EVL MS computer science student Dennis Chau volunteered to teach a one-day computer-programming workshop to 15 Chicago teens as part of The Chicago Code Workshop. The Workshop is a private/non-profit partnership to provide hands-on technology learning experiences to underprivileged kids. They taught the Processing programming language to enable the kids to quickly create images. They continued to add more complexity so that by the end of the day, the students had created simple interactive art applications where mouse inputs moved a shape around on the screen and changed its colors.

August 12, 2011. Maxine Brown gave an overview of EVL research to members of the University of Illinois Foundation Telemarketing Call Center staff (2 full-time staff and about 20 student supervisors).

May 13, 2011. Calit2 built and deployed two OptIPortables running SAGE to community centers in the San Diego area. They previously brought in staff and students who work/visit the center to teach them SAGE. Calit2 is deploying OptIPortables to assist underserved communities in San Diego interact with one another and with UCSD, without leaving their own neighborhoods. The technology is expected to be particularly useful because underserved communities in San Diego are often so geographically distant from academic and commercial centers (and from one another) that it can impede education, job growth and social reform. One is deployed to South Metro Career Center (SMCC), an African-American community center in San Diego's Mount Hope community, and another to Casa Familiar, a Mexican-American center in San Ysidro. The hope is that both organizations will network with one another via their OptIPortables and to Calit2 to enable communities to share experiences, content and programs with one another and be tightly coupled with UCSD students. More information is available at <http://www.calit2.net/newsroom/article.php?id=1808>.

In February 2011, prior to deployment, Calit2 began conducting 4-hour SAGE training sessions on Fridays. One attendee wrote, in an email to Tom DeFanti and Ramesh Rao, "The capability of the walls to enable exchange – images, process, info – is powerful and it got us all thinking of endless possibilities for their use in enabling new modalities of community development and pedagogy, the interface between UCSD and these neighborhoods / communities."

Calit2 SAGE training classes

South Metro Career Center's OptIPortable with SAGE

Casa Familiar's OptIPortable with SAGE

April 19, 2011. A science journalism class at Northwestern University's Medill School of Journalism brought students to EVL to learn more about EVL research. Afterwards, several students did their practicum and wrote articles on EVL technologies. In particular, journalism student Ashley Cullins wrote: "Not your usual desk job" <http://news.medill.northwestern.edu/chicago/news.aspx?id=186022> and "Diamonds in the digital rough - female computer scientists shine" <http://news.medill.northwestern.edu/chicago/news.aspx?id=186381>. The latter profiles Jillian Aurisano, an EVL computer science graduate student who is working on a genomics SAGE application with EVL industrial partner Monsanto.

EVL's Jillian Aurisano.

April 13, 2011. EVL hosted teacher Melvin Slater and 30 students from Austin Polytech High who visited the UIC campus under the auspices of the University of Illinois Affiliate Project Lead The Way (PLTW) program.

April 7, 2011. EVL gave tours and demonstrations to high-school girls participating in the UIC Girls and Computer Science Day, hosted by the UIC CS department, WISE (Women in Science and Engineering) and sponsored by Google RISE (Roots In Science and Engineering) Award and Google Chicago.

Maxine Brown gives an EVL overview presentation to WISE high school girls.

EVL grad student Julian Arisano talks to high school girls about her studies in computer science.

Students tour EVL lab; here they use the EVL paint program on Cyber-Commons.

April 6, 2011. EVL graduate student Jillian Aurisano hosted a local troupe of ~30 Girl Scouts ("Brownies," ages 7-9). They primarily got hands-on demonstrations of the technologies, and thought it the best field trip, ever! Some now want to be professors when they grow up.

EVL grad student Jillian Aurisano explains the Paint program to the young Girl Scouts.

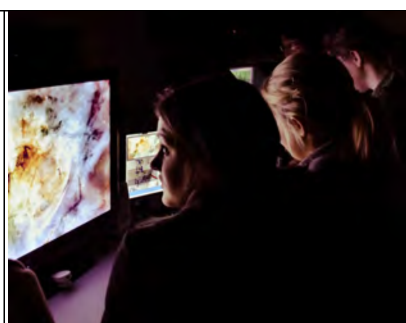
EVL grad student Jullian Aurisano talks to the Girl Scouts about her career in computer science.

Girl Scouts interact with EVL's TacTile display and POL video game.

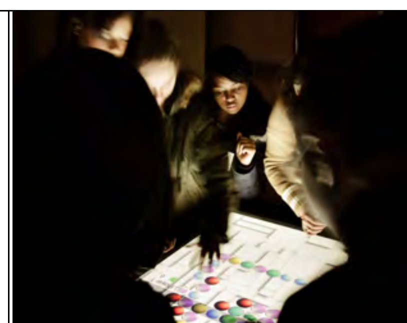
April 1, 2011. EVL gave tours/demos to ~60 students attending the University of Illinois' Communication Colloquium, which provides a forum for communications grad students from University of Illinois campuses (Chicago, Urbana-Champaign, Springfield) to meet and to present their work.

March 1, 2011. EVL graduate student Jillian Aurisano hosted 20 high-school girls attending the UIC WISE GEM-SET pre-college outreach program (Women in Science and Engineering Program's Mentoring for Success, a grant funded by the US Department of Education Women's Educational Equity Act WEEA Program).

WISE high-school girls learn about EVL's LambdaTable/RainTable.



WISE high-school girls learn about EVL's Project Lifelike.



WISE high-school girls learn about EVL's TacTile display.

February 23, 2011. EVL did a talk/demos for the UIC College of Engineering's Engineering 100 course. Engineering 100 is a general orientation class for undergraduates taught by Dr. Chris Kuypers, associate director of the COE Academic Resource Center. As part of the course, students are divided into groups according to their majors and Teaching Assistants (TAs) in those respective majors provide more specific information about coursework, careers and real-world applications. Computer-science TA Phil Pilosi, *who* *also works part-time at EVL through funds obtained from the National Science Foundation's (NSF) Research Experiences for Undergraduates (REU) program,* organized the “field trip” to EVL. Approximately 80 incoming computer-science majors visited EVL in two groups, on October 4 and 6, to learn about EVL’s many advanced visualization research and development activities. “The overwhelming response was ‘Wow!’”, Pilosi said, “as they learned that computer science can be fun.”

February 21, 2011. EVL hosted a one-hour open house for UIC Engineers Week. In addition, 7 cub scouts (+ 1 sister) and their parents who were also interested in seeing EVL were invited to attend, too.

EVL’s Andy Johnson uses SAGE to present a Lab overview to Engineers Week attendees.

Cub scouts play student-developed videogame “POL” on EVL’s TacTile.

Engineers Week attendees fly over the planet Mars on EVL’s Varrier autostereo display system.

February 8-11, 2011. EVL hosted Anne Koval and Frank Jackson, two journalism graduate students from the Northwestern Medill School of Journalism, who were doing one-week practicums at EVL.

February 4, 2011. EVL and collaborator Steve Jones from the UIC Communications Department hosted a program officer from the McCormick Foundation. The McCormick Foundation is interested in new media, teens, social networking and journalism. In particular, the program officer was interested in collaboration technologies and in deploying these technologies to schools, youth centers, etc. EVL demonstrated Cyber-Commons and SAGE.

October 29, 2010. Luc Renambot of EVL participated in the UIC 2010 Frank Armitage Lecture in Biomedical Visualization, which features “visual geniuses” in medical and scientific illustration, animation, imaging and direction. On the last day of the meeting, Renambot hosted 35 attendees at EVL, giving a presentation and demonstrations of the Lab’s research efforts.

October 27, 2010. Andy Johnson and Maxine Brown of EVL hosted teacher Mel Slater and 18 students from Chicago’s Austin Polytechnic High School as part of the University of Illinois Affiliate Project Lead The Way (PLTW) program. The students wrote a review of their trip to UIC for their school paper, noting, “We found out that the lab [EVL] was founded in 1973 and Jason Leigh is the current director. The lab supports about 18 graduate students and 6 undergraduate students. The lab researches advanced display systems, visualization systems, high-speed networking and more. This gave students an example of what a particular day at college would be like…”

October 26, 2010. Marcella McCarthy, a graduate student at Northwestern Medill School of Journalism, spent her one-week practicum at EVL and wrote several articles about the students and the technology.

October 12, 2010. EVL hosted journalism students from Northwestern University's Medill School. Their professor, Donna Leff, takes her students to visit a variety of places, with the goal of having the students write articles about subjects they find interesting.

September 24, 2010. EVL hosted 2nd graders from a local school (a UIC employee's child and her friends). They enjoyed EVL's interactive environments.

2.B. Research Findings

2.B.1. SAGE Multi-user Interaction: Design Goals

Given how little is known about tiled display wall usage in real-world scenarios, the plugin-based architecture of the SAGE Direct Interaction Manager (DIM) and SAGE Widgets is ideal for adding and modifying overlays and devices. Decoupling the event handling logic, drawing and creation achieved a truly distributed interaction framework. Widgets can be seamlessly drawn across any number of displays driven by any number of display nodes. Widgets automatically scale to any target display size and resolution. Furthermore, since there is no theoretical limit on the number of connected physical interaction devices, concurrent multi-user interaction is natively supported by providing a separate cursor for each device. While rules exist to prevent multiple devices from interacting with the same widget simultaneously, no such rules are enforced between widgets; hence, multiple users can interact with different widgets simultaneously, even within the same application. Hence, EVL achieved its initial design goals (described in Section 2.A.7.1), as explained below.

Distributed: By decoupling the widget logic, drawing and creation, we achieved a truly distributed widget framework. Widgets can seamlessly be drawn across any number of displays, and driven by any number of Display Nodes. Applications located on remote rendering resources can present their user interface on any display by requesting widgets and receiving events over the network, all without ever being aware of this separation. The separation means that we can develop new interaction techniques that are more appropriate for large-scale, high-resolution displays without requiring modifications to the applications themselves. For example, as display resolution dramatically increases, target acquisition becomes much more difficult. One approach is to dynamically resize targets as cursors get near, which is something we were able to easily implement without changing or recompiling any of the applications.

Scalable: During startup, DIM first collects information about the display environment and calculates the appropriate widget scale factor to adjust for *usability* (ease of clicking on a target with a physical interaction device) and *visibility* (font size visible on the display). To provide truly scalable drawing, we use dynamically resizable vector fonts and large raster images that are typically scaled down to reduce aliasing. It would be straightforward to add support for vector images as well. Since we always assume that applications are rendered remotely, we cannot assume that every image used in the application interface is already present on the display side. Therefore, the API automatically embeds necessary images in the XML widget description, which is then delivered to the Display Nodes for drawing. This gives application developers freedom to design custom interfaces.

Multi-user: DIM was designed to support multiple interaction devices while giving each device a separate cursor. Additionally, while rules exist to prevent multiple devices from interacting with one widget at the same time, no such rules are enforced between widgets; hence, multiple users can interact with different widgets simultaneously, even within the same application.

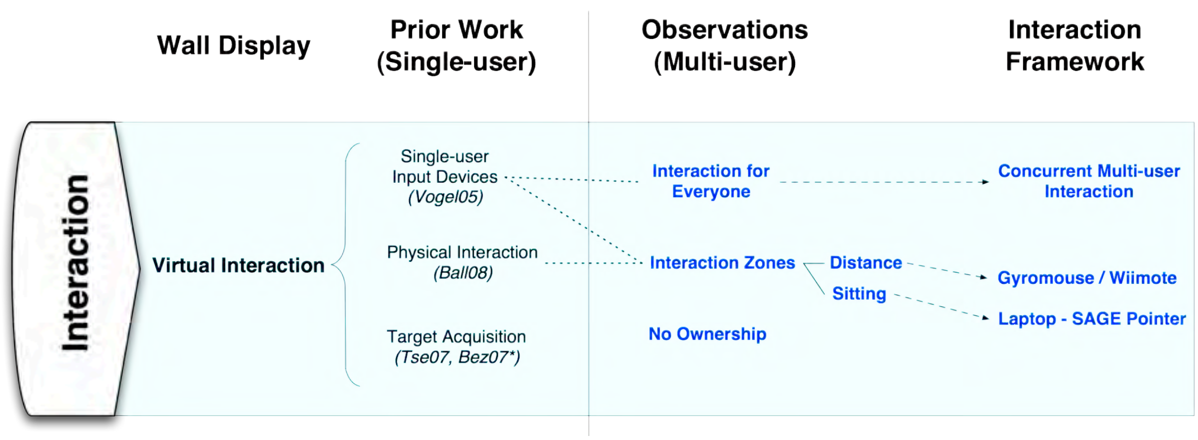
Multi-modal: Both new physical interaction devices will appear on the market that perform better on large high-resolution displays and, as we personally experienced, new combinations of multiple input modalities will be more intuitive for different use cases. New devices can be added to SAGE by providing a plugin that describes the conversion between device-specific events and a generic set of events. By using this generic set of events – therefore removing any specifics for each device – we treat all of them equally for event handling purposes.

The SAGE interaction framework is ideal for empowering collaboration on tiled display walls for the purposes of further research of potential applications and human factor issues in digital war rooms. This would not be possible using existing interaction systems since they do not fully exploit the affordances of such displays.

2.B.2. SAGE Multi-user Interaction: Design Improvements

The following diagram summarizes the current state of the interaction framework with early observations of SAGE use and the resulting features highlighted in blue. The early observations of SAGE use in weekly EVL meetings and a UIC anatomy class indicated clear needs for direct interaction capabilities for multiple users simultaneously. This was the primary motivation for the development of the interaction framework that enabled the variety of use cases presented in this document.

Furthermore, early observations also revealed two distinct interaction zones for users: from a distance and from a sitting position. Direct interaction from a distance was supported by various physical interaction devices, of which Gyromouse and the Wiimote were the most suitable. Because of its large operating range, Gyromouse was particularly appropriate for encouraging physical navigation. Interaction while sitting was enabled through SAGE Pointer, enabling direct interaction and pointing from a laptop. While the Gyromouse or the Wiimote aren't novel input devices, they allow concurrent multi-user interaction, which was our goal.



Enabling direct interaction: Observations and the resulting framework improvements are highlighted in blue.

2.B.3. Reconfigurable Display Space Organization: Observations

Working on tiled display walls closely mirrors the kinds of activities found in traditional paper-based war rooms and project rooms. Collaboration is amplified due to two factors: users are able to collectively externalize and organize all the relevant information and, users maintain a constant spatial awareness of the information and the experts in the room. Observations of users in SAGE revealed the following:

Partitioning the Display Space: Partitioning the display space was frequently employed to designate individual workspaces for each user and to spatially categorize information.

Individual Organization Preferences: Users seemed to embrace the ability to organize their own display space without interfering with others and, if allowed to exercise their individual preferences, they are more likely to adopt wall displays as a collaborative medium.

Sense of Ownership: During collaborative work, users seem to respect each other's window ownership and personal space, even if not explicitly defined. This suggests that social protocols may be sufficient for coordinating control among groups of users.

Supporting Reorganization: When users are engaged in analysis or sense-making tasks, viewing information arranged in different logical arrangements can bring about different perspectives – a phenomenon often referred to as the Rashomon Effect.

Structure vs. Freedom: Although automatic layout features are very useful in structuring an environment, users will always want the freedom to fine-tune the layout to exactly fit their needs.

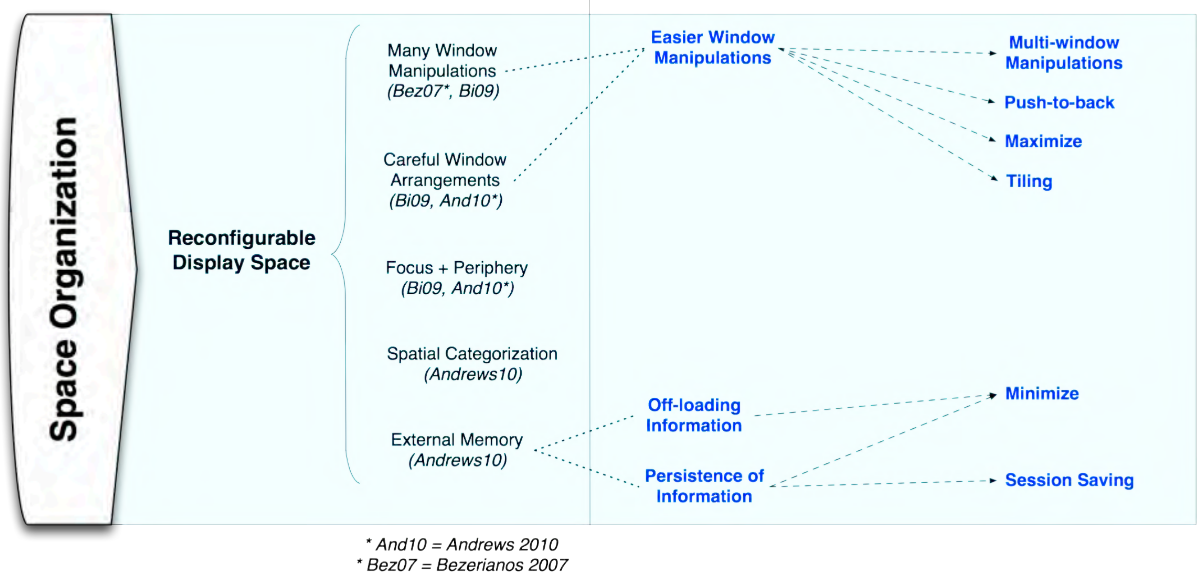
Organization Learning Curve: Display space organization became a necessary part of the workflow; however, it is evident that using the space effectively is a skill to be learned. Perhaps the system can monitor the state of the display and assist with organization given any meta-data that might be available about the content being displayed.

Offline Preparation: Users have a need to prepare for meetings ahead of time by scripting the presentation from their desktop or laptop computers using a virtual template of the tiled display wall.

2.B.4. Reconfigurable Display Space Organization: Design Improvements

The following diagram summarizes the current state of the display-space organization framework with the latest observations and the resulting features highlighted in blue. Prior research has pointed out that users frequently perform many window manipulations and careful window arrangements on wall-sized displays, which was further supported by our observations. To assist window manipulations, several manual and automatic organization techniques were developed. While not perfect, the automatic organization techniques often eliminated the need for careful manual window arrangements, greatly saving time and effort.

As observed during the Visual Analytics class, a large amount of screen space supports "external memory" by eliminating the need for students to memorize information. However, even high-resolution displays are not enough for keeping all the information visible, which necessitates off-loading of information. The developed *minimize* feature serves external memory by keeping the off-loaded information around, in the exact region where it was minimized. To further assist window identification, minimized windows still have the same aspect ratio as their un-minimized state; i.e., their content is still displayed fully (e.g., a movie is still visibly playing while minimized). When off-loading information isn't enough, the whole state of the display can be saved and recalled at a later time by browsing screenshots of the saved states.

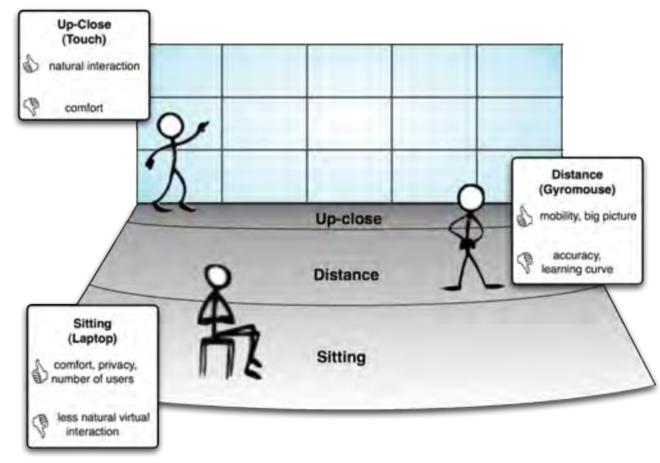


Enabling display-space organization through easier window manipulation techniques:
Observations and the resulting framework improvements are highlighted in blue.

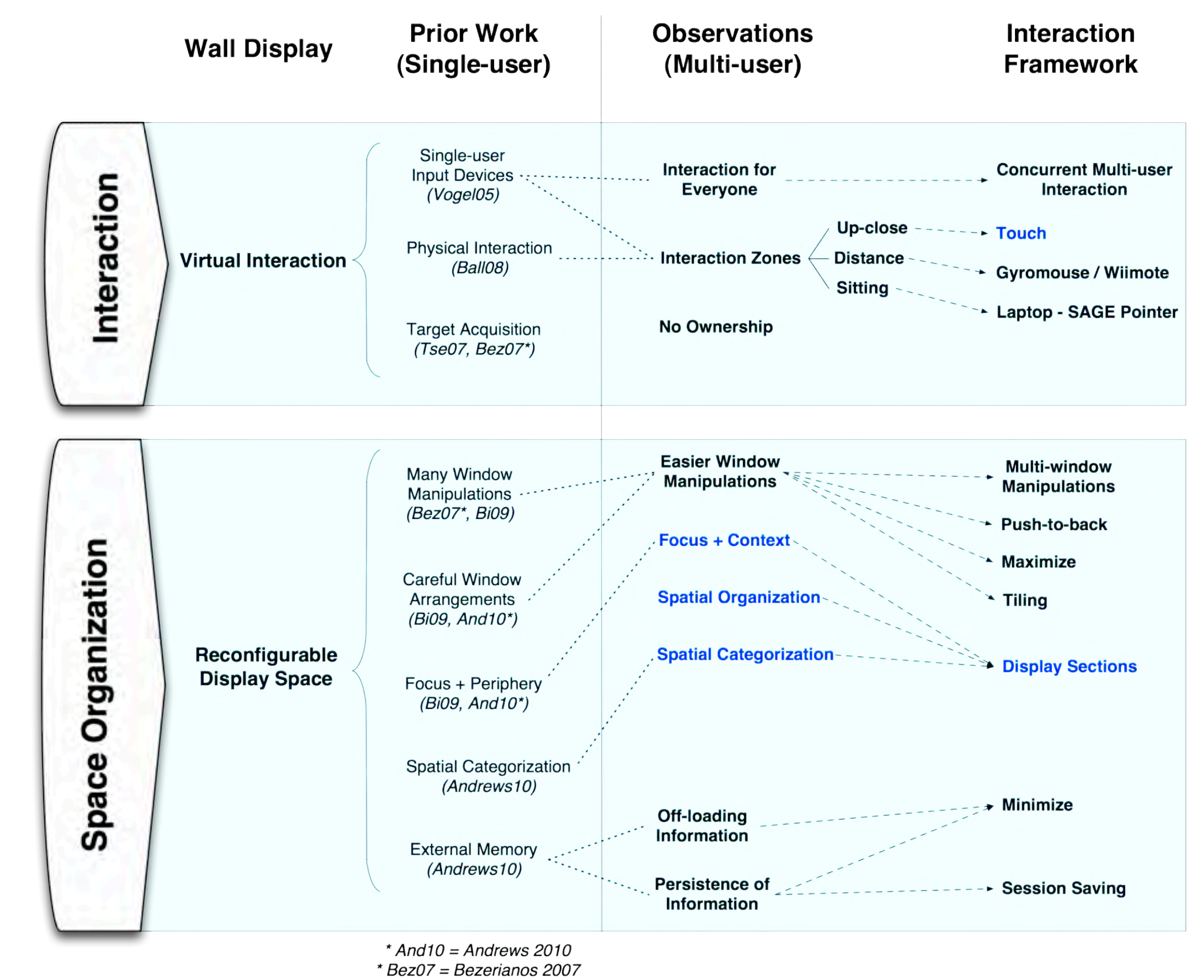
2.B.5. Up-close Interaction and Display Partitioning: Design Improvements

Recent technological advancements by PQ Labs made it possible to add touch capability to the EVL Cyber-Commons wall. Although an early prototype with limited response rate, it was sufficient for devising several crucial touch gestures to support concurrent, multi-user up-close interaction. Most importantly, the addition of the touch input modality has the potential to further encourage more natural physical navigation. A summary of all interaction zones and their affordances is presented in this illustration.

The following diagram shows the current state of the interaction framework with the latest observations and the resulting features highlighted in blue.



Summary of the 3 commonly used interaction zones in wall display environments.



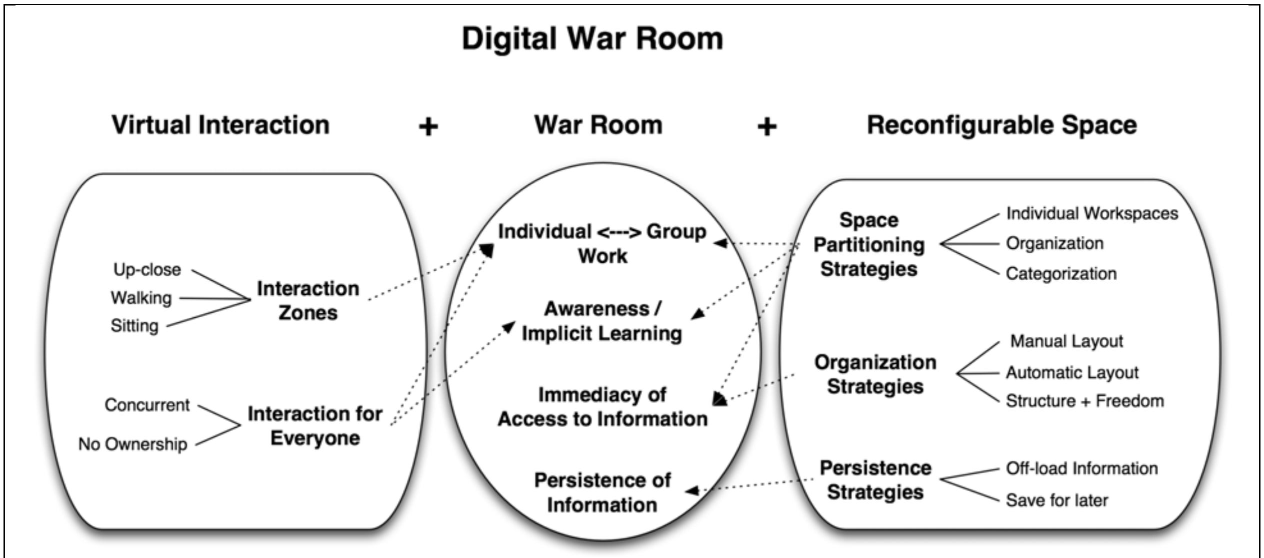
Our final user-interface design phase brought together the touch interface as another interaction zone and display sections for space partitioning. Observations and the resulting framework improvements are highlighted in blue.

Although EVL's Cyber-Commons was treated as a contiguous display, thanks to its thin bezels, users still logically divided the display space to serve several different needs. Aside from spatial categorization, space was also used for maintaining various organizations of information and for supporting focal and context regions during tasks. Unlike prior work, which reported that in single-user environments the center is the focal region, the observed collaborative use cases indicated that focal regions change often and depend on the use case.

2.B.6. The Digital War Room

Traditional war rooms have the potential to significantly increase the productivity of teams through radical collocation. Walls covered with paper artifacts are the primary tools that foster social interactions in such environments. The goal of the SAGE user interface was to begin a shift towards digital war rooms using tiled display walls to enhance traditional paper-based environments with virtual interaction and reconfigurable space for collaboratively managing large amounts of visual information.

Teasley[1] identified four fundamental affordances of war rooms responsible for productivity increase in teams. They were listed as constant awareness and implicit learning, easy transitions in and out of spontaneous meetings, immediate access to information and its persistence. ***Substituting paper-based walls with large-scale, high-resolution displays introduces two additional affordances, among others. First, digital walls enable virtual interaction with the artifacts, enriching interaction opportunities through various interaction zones. Second, digital space is easily reconfigurable, unlike walls covered with paper artifacts.*** Combining these affordances begins to paint the picture of digital war rooms. The following diagram illustrates how important techniques in interaction and display space organization complement traditional war rooms.



Digital war rooms are a combination of traditional war rooms and high-resolution displays, which provide the benefits of virtual interaction and reconfigurable space. The arrows outline how techniques serve to support the traditional war room affordances.

1 Teasley, Stephanie, Lisa Covi, M.S. Krishnan, and Judith S. Olson. 2000. *How does radical collocation help a team succeed?* ACM, December 2000, doi:10.1145/358916.359005.

2.B.7. Use Cases: Collaborative Analysis User Studies

Details of observations and user feedback from case studies discussed in Section 2.A.10 are summarized here, but are described in full in the paper: Ratko Jagodic, "An Exploratory Study of Collaborative Work on Large High-Resolution Displays" – submitted to CSCW 2012 and currently under review.

User Feedback

Even though some users in the beginning were skeptical about the advantages of a wall display in this task, in the end, impressions and feedback from all the groups were very positive. The ability to simultaneously interact with and view all the information at once helped immensely in this collaboration. Most suggestions revolved around SAGE usability issues, which can be categorized as follows:

Improved Feedback and Awareness: Given such a large working surface, it is often difficult to make note of all the activity on the wall and therefore it would be useful to animate changes. Besides the obvious aesthetic benefits, this would have the potential to increase awareness since human peripheral vision is naturally sensitive to motion. For instance, users noted that it would have been helpful to animate the tiling process in order to more easily keep track of automatic rearrangements and minimize the effect on spatial memory. Similarly, one could animate new windows showing up on the display.

The Learning Curve: All users reported being more comfortable with the technology after the study and having a better idea of how to organize information with so much space available. Most claimed they would have paid more attention to organization and made more use of sections and tiling features if they had to do it again. Additionally, virtually every group overlooked a certain available feature, which could have simplified some actions or even resulted in a new task strategy.

Easier Control Switching: Although the "extended desktop" metaphor for switching control from laptops to SAGE made sense, users were sometimes confused about which display they were currently controlling. This was mostly due to technical reasons, such as insufficient feedback and responsiveness.

Annotation: On a really large surface with many windows, identifying windows becomes difficult, especially when documents are visually similar, as in this use case (primarily white, text documents). Users cited annotation and editing on the wall as much-needed features to mitigate this problem.

Design Implications From Observations

Aside from user feedback, we observed and abstracted several high-level design goals to better support collaborative work on wall displays.

Individual Workspaces: Participants seemed to embrace the ability to organize their own display space without interfering with others. We believe that if we allow users to exercise their individual preferences instead of forcing structure on them, they will be more likely to adopt large high-resolution displays as a collaborative medium.

Structure + Freedom: Managing a large number of windows manually proved tedious for many users, which encouraged them to use sections and automatic tiling features. Although sections proved very useful in structuring the environment, they frequently got in the way of accomplishing simple, mostly temporary, tasks. This led to user frustration and diminished the benefit of sections, occasionally prompting users to remove sections altogether in order to gain complete freedom of interaction. Perhaps a layer of unrestricted window layout could be superimposed on top of a structured layout to allow a degree of freedom.

Allow Transient Organization: Even in this simple task, users sometimes attempted various layouts to better suit the current subtask. In a more complicated analytic task, gaining new insights about data could greatly depend on one's ability to represent it in many different forms. Therefore, reorganizing information quickly and switching between different layouts will be crucial.

Undo: Since organization is now a task in itself, users will inevitably make mistakes. Or even worse, the system will make mistakes if it attempts to be intelligent. The ability to *undo* a previous action or a set of actions is imperative. However, limiting the feature to undoing only the last window manipulation is not sufficient. Perhaps a timeline approach would be more appropriate. Additionally, users might have many organizational structures on the display at once, which means it should be possible to undo actions selectively on certain portions of the display. Given a large number of windows and difficulty in identifying them, windows get closed by accident, which should be reversible as well.

Assist With Organization: Considering that users sometimes forget to organize until clutter becomes obvious, the system could continuously monitor the space, learn about users' actions and detect a state of clutter. It could either remind users to organize or even offer suggestions based on the gathered data. Defining metrics for identifying the state of clutter would depend on the use case, but could include the amount of overlap in windows, the number of windows, window sizes, amount of empty space and possibly the number of interactions.

2.C. Research Training and Development

NSF's many CI initiatives are amassing terabytes to petabytes of data, and will soon reach exabytes. EVL's SAGE efforts will enable users to connect visualization pipelines running on supercomputers, data storage systems and/or instruments to ultra-resolution tiled display walls.

In addition to advancing Computer Science, this project will help advance knowledge and understanding in the domain sciences, by providing faculty, staff and students with a means to manage the scale and complexity in their data with an intuitive environment for controlling cyberinfrastructure-enabled resources.

Those involved in this project extend outside the boundaries of UIC, given EVL's other collaborators -- on campus, nationally (museums, NCSA Great Lakes Consortium for Petascale Computing partners, DOE/SciDAC partners), and internationally (via StarLight, PRAGMA and GLIF). All the people working on display-related projects – computer scientists building infrastructure and the domain scientists who use it – are involved in furthering research; either by contributing to SAGE's development or by helping us better understand the limitations and future directions of our activities. It is clearly our students who benefit most, and are in high demand by the commercial sector for jobs in R&D when they graduate.

Making SAGE open-source has enabled greater participation by industry partners, including Monsanto, NTT Network Innovation Laboratories, Sharp Laboratories of America, Rincon, Ciena and Microsoft Research. They want to understand their future customers, so are working with EVL to prototype ideas and solutions.

2.D. Outreach Activities

For detailed information, see Section 2.A.5: Education, Outreach and Broader Participation.

EVL is committed to diversity and deems it central to its programs, projects, and activities, and provides research assistantships to graduate students, support for Research Experiences for Undergraduates (REUs), and mentoring programs for high-school students from the Illinois Math and Science Academy. Also, EVL faculty uses the technologies and tools it develops in the classroom, helping train the next-generation workforce.

In addition, EVL is very active in UIC College of Engineering and Computer Science recruitment and minority outreach activities, and does demonstrations and presentations for several Computer Science Open Houses (for local high-school kids) per year, the annual Engineering Open House, "Bring Your Daughters to Work" day, the Society of Women Engineers (SWE), and the Association for Computing Machinery (ACM) student chapter, among others.

To reach out to domain scientists and other computer scientists, EVL participates in major computer science conferences (e.g., ACM/IEEE Supercomputing), workshops (e.g., PRAGMA, GLIF), and domain-science conferences (e.g., TeraGrid, AGU). EVL disseminates information via its website, YouTube, conference presentations, journal articles, and media promotion.

EVL also actively works with museums, another outlet for broad dissemination to the public; we currently work closely with Adler Planetarium in Chicago and the Science Museum of Minnesota.

EVL attracts a disproportionately higher number of underrepresented students than other CS departments because of its joint program with the Art & Design Department, and its many collaborations with humanities, engineering, medicine and science. UIC has a higher percentage of Latino and African-

American students than any Big 10 university and ranks 44th (of over 2,000 universities) in the number of BA degrees awarded to Latinos and African-Americans. At the graduate level, UIC is ranked 26th in MA degrees awarded to Latinos and African-Americans.

3. Publications and Products

3.A. Journal Publications

Jason Leigh, Andrew Johnson, Luc Renambot, Tom Peterka, Byungil Jeong, Daniel J. Sandin, Jonas Talandis, Ratko Jagodic, Sungwon Nam, Hyejung Hur, Yiwen Sun, "Scalable Resolution Display Walls," Proceedings of the IEEE, submitted.

R. Jagodic, L. Renambot, A. Johnson, J. Leigh, S. Deshpande, "Enabling multi-user interaction in large high-resolution distributed environments," Future Generation Computer Systems (Special issue on CineGrid: Super high definition media over optical networks, edited by Cees de Laat, Paul Hearty and Naohisa Ohta), Elsevier, Volume 27, Issue 7, July 2011, pp. 914-923 <http://dx.doi.org/10.1016/j.future.2010.11.018>

Thomas A. DeFanti, Daniel Acevedo, Richard A. Ainsworth, Maxine D. Brown, Steven Cutchin, Gregory Dawe, Kai-Uwe Doerr, Andrew Johnson, Chris Knox, Robert Kooima, Falko Kuester, Jason Leigh, Lance Long, Peter Otto, Vid Petrovic, Kevin Ponto, Andrew Prudhomme, Ramesh Rao, Luc Renambot, Daniel J. Sandin, Jurgen P. Schulze, Larry Smarr, Madhu Srinivasan, Philip Weber, Gregory Wickham, "The Future of the CAVE," Central European Journal of Engineering's Online First, published by Versita with Springer-Verlag GmbH, November 2, 2010 <dx.doi.org/10.2478/s13531-010-0002-5>

3.B. Books / Publications

Ratko Jagodic, Collaborative Interaction And Display Space Organization In Large High-Resolution Environments, PhD Dissertation, Electronic Visualization Laboratory, University of Illinois at Chicago, July 2011 <http://www.evl.uic.edu/files/pdf/Jagodic_Ratko.pdf>

Jason Leigh, "Visualization of Large-Scale Distributed Data" (chapter), Data Intensive Distributed Computing: Challenges and Solutions for Large-scale Information Management, Tevfik Kosar (editor), IGI Global, July 30, 2011. <http://www.amazon.com/s/ref=nb_sb_noss?url=search-alias%3Dstripbooks&field-keywords=Data+Intensive+Distributed+Computing%3A+Challenges+and+Solutions+for+Large-scale+Information+Management&x=15&y=11>

3.C. Internet Dissemination

www.sagecommons.org

3.D. Other Specific Products

Other than the information reported here, we have not developed any other specific product of significance.

4. Contributions

4.A. Contributions within Discipline

Since 2002, EVL has been conducting research in the use of high-performance remote rendering and streaming as a possible solution to the large-scale data visualization problem. This approach performs the "heavy lifting" of accessing, filtering and visualizing the data, using NSF cyberinfrastructure investments in the TeraGrid, high-speed national networks (such as National LambdaRail and Internet2), and relies on instruments, such as the Cyber-Commons and SAGE, to view the results.

SAGE development opens up new opportunities in computer science research at the intersection of large-scale data visualization, human-computer interaction, virtual reality, and high-speed networking. In addition, SAGE is being used to support several UIC classes and seminars taught in the Computer Science, Art and Design, and Physics departments.

4.B. Contributions to Other Disciplines

Coping with complexity and scale in data is a problem that spans all of e-science. The Nation's cyberinfrastructure initiatives are amassing terabytes to petabytes of data, which will soon reach exabytes. When NCSA Blue Waters comes online, the only way to access it will be over networks. SAGE can provide scientists with a conduit into visualizing petascale computations.

Today, ultra-resolution display environments are the "lenses" of virtual "microscopes" and "telescopes," enabling researchers to observe the data in cyberinfrastructure repositories. Using SAGE, scientists can create visualization pipelines from multiple sources -- whether supercomputers, data storage systems and/or instruments (such as high-definition cameras), as well as laptop screens and the Web -- to access and share a variety of information, in a variety of resolutions and formats, and create giant cyber-mashups. These "digital war rooms" enable users to access up-to-date, related sets of information and simultaneously display them, to quickly see context as well as details and make more informed and timely decisions. This is unprecedented and heretofore not available, and will have a profound and transformative effect on data visualization, data exploration and collaboration, making cyberinfrastructure more accessible to end systems and to end users, both in the laboratory and in the classroom.

4.C. Contributions to Human Resource Development

Tiled display walls and SAGE are transformative technologies that are changing the way today's scientists and future scientists manage large-scale and complex data -- in order to more rapidly discover the underlying causes and solve problems of national priority, such as global climate change or disaster response. We firmly believe that we need to give scientists and students better technologies in the laboratory and classroom than they currently have at home. At EVL, SAGE and tiled display walls provide a community resource openly accessible to our faculty and students, where they gather, meet, study, and work. In addition, EVL employs graduate and undergraduate students to help build the technologies, and our faculty uses it in the classroom, helping train the next-generation workforce.

4.D. Contributions to Resources for Research and Education

Our Nation already invests in network-connected, middleware-enabled cyberinfrastructure to generate and disseminate petabytes (ultimately exabytes) of data among researchers worldwide. What is missing, however, is a globally integrated collaborative work environment to facilitate data analysis and high productivity. The SAGE User Community believes SAGE and tiled display walls can fulfill that need, and are adapting these technologies to use in such diverse disciplines as: geoscience, homeland security, bioscience, cosmology, atmospheric science, chemistry, computer science, medicine and art.

A few groups already use SAGE and tiled display walls in the classroom, giving the next-generation workforce access to these advanced technologies. And, industry is starting to partner with visualization and networking researchers to better understand and use these technologies. For example, Monsanto provided an EVL student with a summer 2011 internship, both at their headquarters in St. Louis, Missouri, and at their Research Center in Bangalore, India. And, KISTI has expressed interest in supporting a graduate student to help tailor SAGE to their educational requirements. Providing a production-quality SAGE will make cyberinfrastructure more accessible to broader communities of scientists and students, and help maintain US leadership in high-performance computing.

4.E. Contributions Beyond Science and Engineering

A "cyber-mashup," or juxtapositions of information, is a transformative high-productivity tool. It is a critical component of data analysis, enabling people to gain more holistic views and insight regarding complex issues, and to make more informed observations and discoveries. SAGE leverages low-cost scalable thin-client PC clusters to enable end users to interactively access remote visualization data objects from shared cyberinfrastructure, as easily as the Web makes access to remote lower-resolution images today.

Technology costs have dropped to the point that adoption of these once-considered high-end technologies is now affordable. EVL actively works with museums; EVL currently works with Adler Planetarium in Chicago and the Science Museum of Minnesota, who employ our tools and technologies in their instructional exhibitions to educate the general public.

In addition, EVL has a number of industry research groups interested in SAGE and tiled display walls; notably, Monsanto, NTT Network Innovation Laboratories, Sharp Laboratories of America, Rincon, Ciena and Microsoft Research. EVL's prior visualization systems, including the CAVE, ImmersaDesk, and GeoWall, created new hardware and software companies and new jobs for Americans, to commercialize and/or use these systems in research institutions and companies.

5. Conference Proceedings

NSF FastLane wants published papers. Instructions state: If you are unable to locate your Conference Proceeding citation using the search, you may manually add your Conference Proceedings in the "Books or Other One-Time Publication" tab under Publications and Products.

Ratko Jagodic, “An Exploratory Study of Collaborative Work on Large High-Resolution Displays,” CSCW 2012, submitted.

Y.C. Chen, R. Jagodic, A. Johnson, J. Leigh, “Cross-Cultural Scientific Collaboration Case Studies” (position paper), Workshop on The Changing Dynamics of Scientific Collaborations, 44th Hawaii International Conference on System Sciences 2011, Koloa, Hawaii, January 2011 <http://www.evl.uic.edu/core.php?mod=4&type=3&indi=439>

6. Special Requirements

6.A. Objectives and Scope

A brief summary of the work to be performed during the next year of support if changed from the original proposal.
Our scope of work has not changed.

6.B. Special Reporting Requirements

Do special terms and conditions of your award require you to report any specific information that you have not yet reported?
No.

6.C. Animals, Biohazards, Human Subjects

Has there been any significant change in animal care and use, biohazards, or use of human subjects from what was originally approved (or approved later)?
No.