“Alone it would be work – together it was fun”

Interactive and Collaborative Information Visualization

Petra Isenberg
My Background

• Diplom, Computational Visualistics
  University of Magdeburg, Germany

• PhD, Computer Science
  University of Calgary, Canada

• PostDoc

• Now: Research Scientist
  INRIA, France
My Background
My Background
My Background
My Background
Why do we do...

COLLABORATIVE INFOVIS?
It is estimated that 800 exabyte (800x 10^19) of digital information will be generated this year
Data
Size
Complexity
Availability
Importance
AN EXAMPLE...
GenBank Entries

Molecular Biology
“Understanding this complexity requires experts in many different domains”


Molecular Biology
“These days success in being a biologist depends more on one’s ability to collaborate than ever before.”

Molecular Biology
Collaborative Data Analysis

Source: Study of collaboration in biology with Matthew Tobiasz, Sheelagh Carpendale
First we need to learn a little about ...
The Problem

The world is getting more complex, and problems are getting more urgent. These must be dealt with **collectively**. However, human abilities to deal collectively with complex / urgent problems are not increasing as fast as these problems.

If you could do something to improve human capability to deal with these problems, then you'd really contribute something basic.

...Doug Engelbart

**The early 1950s**
The Vision

... I also had a clear picture that one's colleagues could be sitting in other rooms with similar work stations, tied to the same computer complex, and could be sharing and working and collaborating very closely. And also the assumption that there'd be a lot of new skills, new ways of thinking that would evolve

...Doug Engelbart

The early 1950s
CSCW

1987
Groupware

– software that supports group work
– investigate algorithms & architectures for multi-user systems

Computer Supported Cooperative Work (CSCW)

– knowledge about the context of groupware design
– investigate individual/group/organizational requirements for multi-user systems

Research Goals
“is about groups of users – how to design systems to support their work as a group and how to understand the effect of technology on their work patterns”

Dix, Finlay, Abowd & Beale
Human Computer Interaction, 2nd Ed. Prentice Hall. 1998

“is the study of the electronic workplace – an organization-wide system that integrates information processing and communication activities”

Ellis, Gibbs & Rein
Groupware: some issues and experiences, Comm ACM 34(1) 1991

Definitions
<table>
<thead>
<tr>
<th></th>
<th>same time</th>
<th>different times</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>synchronous</td>
<td>asynchronous</td>
</tr>
<tr>
<td><strong>same place</strong></td>
<td>face to face interactions</td>
<td>continuous task</td>
</tr>
<tr>
<td><strong>co-located</strong></td>
<td>decision rooms</td>
<td></td>
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<tr>
<td></td>
<td>single display groupware</td>
<td></td>
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<tr>
<td></td>
<td>shared table / wall displays</td>
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<tr>
<td></td>
<td>roomware...</td>
<td></td>
</tr>
<tr>
<td><strong>different places</strong></td>
<td>remote interactions</td>
<td>communication+coordination</td>
</tr>
<tr>
<td><strong>remote</strong></td>
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</table>
Multiple people using a single display

– multiple input devices
– simultaneous input
– new interaction widgets
– technical issues (O/S)
– mice vs. direct touch

Single-Display Groupware
<table>
<thead>
<tr>
<th>Same Place (Co-located)</th>
<th>Same Time (Synchronous)</th>
<th>Different Times (Asynchronous)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Place (Co-located)</td>
<td>Face to Face Interactions</td>
<td>Continuous Task</td>
</tr>
<tr>
<td>Different Places (Remote)</td>
<td>Remote Interactions</td>
<td>Communication + Coordination</td>
</tr>
<tr>
<td>Video Conferencing</td>
<td></td>
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<tr>
<td>Instant Messaging</td>
<td></td>
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<tr>
<td>Chats/Muds/Virtual Worlds</td>
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<tr>
<td>Shared Screens</td>
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<tr>
<td>Multi-User Editors</td>
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</tbody>
</table>

**Space/Time Matrix**
Share unaltered single user applications

– technical concerns
  • how regions are captured/transmitted
  • architectural limitations
  • controlling input
  • access control...

– social limitations
  • turntaking
  • control
  • privacy

Shared Screens / Windows
<table>
<thead>
<tr>
<th>Same place</th>
<th>Same time</th>
<th>Different times</th>
<th>Different places</th>
</tr>
</thead>
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<tr>
<td>Co-located</td>
<td>Synchronous</td>
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<td>Remote</td>
</tr>
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<td>Continuous task</td>
<td>Communication + Coordination</td>
<td></td>
</tr>
<tr>
<td>Remote interactions</td>
<td>Email, bulletin boards, blogs, asynchronous conferencing, group calendars, workflow, version control, wikis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Email

• Many styles
  – threaded mail
  – intelligent mail (routing / sorting)
  – structured mail (by speech acts)
  – multimedia mail
  – object-oriented mail
  – distribution lists / elist servers

• Social
  – managing complexity and overloads
  – spam
  – archiving

THREAD ARCS: An Email Thread Visualization
InfoVis 2003

Ack. Saul Greenberg
<table>
<thead>
<tr>
<th>Same Place</th>
<th>Same Time synchronous</th>
<th>Different Times Asynchronous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face to face interactions</td>
<td>continuous task</td>
<td>team rooms, large public displays, shift work groupware, project management</td>
</tr>
<tr>
<td>Remote interactions</td>
<td>communication+coordination</td>
<td></td>
</tr>
</tbody>
</table>

**Space/Time Matrix**
Information delivered across shifts

Control Rooms
concurrent synchronized
people intentionally active at the same time

semi-synchronized
people active in near real time

Mixed
may include active and serial activity

Serial
forces turntaking

Unsynchronized
people use tools at different times

co-located
meeting rooms

video conferences, video wall, etc.

shared work surfaces and editors, shared PCs and windows

rapid email exchanges, delayed IM exchanges

cor-authoring systems, shared calendars

argumentation tools

email and structured messages, electronic conferences

modified from Figure 13.9 in Dix, Finlay, Abowd & Beale, Human Computer Interaction, 2nd Ed. Prentice Hall. 1998

Ack. Saul Greenberg
• computer science
  – consistency techniques, data management, algorithms, user interface design
• sociologists
  – studies of work and social practice
• social psychologists
  – e.g. impact of technology on cognitive and interactional processes
• plus...
  – economics; organisational theorists; educators;

Interdisciplinary
Designing & Studying CSCW Systems

- Needs of a group are different
  → Should be reflected in technology
  → Need to examine what IS different
  → Need to understand differences
COLLABORATIVE INFOVIS
Coverage

Figure 2.1: History of publications in Collaborative Visualization in the IEEE VIS, InfoVis, and VAST conferences. Out of a total of 1356 published papers, 26 are on Collaborative Visualization (shown here), and only three (hatched and indicated by numbers above the respective bars) covered co-located collaborative visualization.
Definition

“Collaborative visualization enhances the traditional visualization by bringing together many experts so that each can contribute toward the common goal of the understanding of the object, phenomenon, or data under investigation.”

Raje et al. (1998)
Definition

“The term “collaborative visualization” refers to a subset of CSCW applications in which control over parameters or products of the scientific visualization process is shared.”

Johnson (1998)
"Collaborative visualization [...] allows geographically separated users to access a shared virtual environment to visualize and manipulate datasets for problem solving without physical travel."

Li et al. (2006)
Definition

“[Social data analysis is] a version of exploratory data analysis that relies on social interaction as source of inspiration and motivation.”

Wattenberg (2005)
Definition

Collaborative visualization is...

• the shared use of
• computer-supported
• visual representations of data
• by > 1 person
• for joint information processing activities
Distributed Collaboration

most early work on architectures ...

Screen Sharing  Broadcast Model  Hybrid

.... and scientific visualization
Distributed Asynchronous Collaboration
Social Data Analysis

- Swivel
- DATA 360
- STATPLOT
- Chartle.net
- verifiable.com
- widgenie
- Timetric
- Track-n-Graph
- Trendrrr
Responsive Workbench

(Krüger et al., 1995; Krüger and Fröhlich, 1994)
Personal Digital Historian

Shen et al., 2002
DTLens

Forlines & Shen et al., 2005
Multidisplay Environments

Forlines et al., 2006, 2008
Focus Now

CO-LOCATED COLLABORATIVE INFORMATION VISUALIZATION
Goal
Challenges:

1. How do people conduct face-to-face analysis?
2. Do we need to redesign visualizations?
3. What data/tasks for collaborative analysis?
1. How do people conduct face-to-face analysis?
Knowledge Crystallization Cycle

Diagram from [Card et al., 1999]
Do four eyes see better than two?

[Mark et al., 2003]

Parse Question → Map 1 Var. To Program → Find Correct Visualization → Validate Visualization → Validate Entire Answer

repeat for additional variables
Exploratory Study
• Observational study
• 12 groups
• 5 types of charts, 2 types of tasks
• Goal: observe analysis activities
Data Analysis Activities
<table>
<thead>
<tr>
<th>Discuss Collab</th>
<th>Validate</th>
<th>Select</th>
<th>Operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parse</td>
<td></td>
<td></td>
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</tr>
<tr>
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<tr>
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</tbody>
</table>
Discuss Collaboration Style

• Discuss task division strategy
• Goal: determine how to solve task as a team
Discuss Collaboration Style

- 3 main strategies adopted
  - Complete task division
  - Independent, parallel work
  - Joint work
# 8 Processes

<p>| | | | |</p>
<table>
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Validate

- Confirm partial or complete solution to task
- Goal: avoid errors in completing the task
8 Processes

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Select

• Pick out charts (views) relevant to a task
• Goal: minimize amount of data to read
Select

Re-location during selection
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Operate

• Higher-level cognitive work on view of data
• Goal: to solve a task or sub-task
<table>
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</tr>
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<td>Browse</td>
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**Individual Work**  ⇐  **Joint Work**
Collab?

Validate?

Clarify?

Browse
Select
Parse
Select
Strategy
Operate
Strategy
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**Temporal Sequence**
Temporal Sequence
40% co-occurrence on average
Design Implications

1. Flexible temporal sequence of processes
2. Support unique approaches
3. Activities differ wrt parallel/joint work
2. Do we need to redesign visualizations? How to redesign the visualization workspace?
Parallel Work

Joint Work

[Isenberg & Carpendale, InfoVis 2007]
Data
Hierarchies from domain of molecular biology
CoTree: Tree Comparison System

[Isenberg & Carpendale, InfoVis 2007]
Design Considerations

Collaborative Environment
- Size of display
- Display config
- Input type
- Resolution

Supporting Social Interaction
- Communication
- Coordination

Designing the Information Visualizations
- Representation
- Presentation
- View
- Interaction

[Isenberg & Carpendale; InfoVis 2007]
[Heer, van Ham, Weaver, Carpendale, Isenberg; Information Visualization—Human-Centered Issues and Perspectives, 2008]
Flexible Data Org

Local Interaction

Replicated Menus

Shared Data Store

Annotation

Comparison

[Isenberg & Carpendale, InfoVis 2007]
Challenges

1. View management / coordination?
2. Allow for unique analysis strategies?
View Coordination

[Tobiasz, Isenberg, & Carpendale, InfoVis 2009]
Lark

[Tobiasz, Isenberg, & Carpendale, InfoVis 2009]
[Tobiasz, Isenberg, & Carpendale, InfoVis 2009]
Modelling the Meta-Visualization
Lark: Coordinating Co-located Collaboration with Information Visualization

Matthew Tobiasz, Petra Isenberg, Sheelagh Carpendale

University of Calgary
CoCoNutTrix

- Parallel Interaction
- Temporal flexibility
- Individual vs. joint work

[Isenberg, Bezerianos, Henry, Carpendale, Fekete, CG&A 29(5), 2009]
CoCoNutTrix: From a Network Layout...
From a Network Layout...
... To a layout representing types of groups
Collaborative Retrofit

• Several Mice & Keyboard
• Fullscreen
• Dialogs → Gestures
• Minimization of global operations
• Glows
• Rep changes
• Minimize global
• Separate areas
• Preferences
• Size
• Simultaneous
• Interactive fps

• Conflicts Reduction?
• View changes?
• Appropriate rep for WE?
• Data referencing?
• Awareness?

Interaction

Missing
Cambiera
Collaborative Brushing and Linking for Co-located Visual Analytics of Document Collections

Petra Isenberg & Danyel Fisher
Microsoft Research
solving the problem collaboratively

9 groups

both: analyzing starting document

CLOSE COLLABORATION

6 groups

one: analyzing starting document
other: exploring other data

LOOSE COLLABORATION
information sharing and collaboration

- different collaboration styles adopted
- allowed flexible investigation based on emerging information
- influenced what data/views were shared

[extended from Tang et al., 2006]
**collaboration styles**

**close collaboration**
- limited interaction with system
- discussion or commentary
**collaboration styles**

**close collaboration**
- same document read
- same search result browsed

**SHARED VIEW**

**SAME INFORMATION DIFFERENT VIEWS**

**close collaboration**

**loose collaboration**
**collaboration styles**

**close collaboration**
- different documents from the same search
- e.g. divide and conquer to find relevant document
collaboration styles

loose collaboration
• same general question/hypothesis
• different starting points (searches)

SAME GENERAL PROBLEM

close collaboration  loose collaboration
collaboration styles

loose collaboration
• work on different hypotheses, paths throught data
• conversation rare

close collaboration

loose collaboration
temporal analysis

close collaboration

loose collaboration

DISC  VE  SV  SIDV  SSP  SGP  DP  D

Group 2

Group 5

92% Closely Coupled

33% Closely Coupled

Task time
4 most closely collaborating teams

loosely collaborating teams

Group 2

Group 5
“sometimes [my partner] and I fight about who gets to use the computer so it was nice to share that. One person standing and another sitting that’s never a collaborative act here we’re assembling a whole thing together.”

**tabletop for data analysis?**

**pros:**
- shared context (sharing, discussion, awareness)
- variety of work styles supported (with our design)
- fluid strategy changes possible
- software approached & used without technical barriers

**cons:**
- not all collaboration strategies successful
- our table too small
- virtual keyboard cumbersome
implications for design

- design for transient behavior
  - strategies change & interfaces need to accommodate
  - allow teams to choose collaboration style best suited to task and team setup
  - design system features to support different styles
- encourage closely coupled work
  - awareness features possibly not strong enough for loosely-coupled teams
  - make common information even more obvious
2. Do we need to redesign visualizations? How do we need to the visualization workspace? How do we need to redesign interaction techniques?
iLoupe + iPodLoupe
[Voida, Stromer, Tobiasz, Isenberg, Carpendale, ITS 2009]

Gestures for information selection
[North, Dwyer, Lee, Fisher, Isenberg, Robertson, Inkpen; Interact 2009]

Touch interaction for 3D astronomical data
[Yu, Scetachov, Isenberg, Everts, Isenberg, submitted]
Summary

• Understanding Collaborative Analysis
  – Analysis Processes
  – Fluid Transitions
  – Individual vs. Joint Work

• Designing Collaborative Analysis Systems
  – Design Considerations
  – Design Examples
  – Retrofitting Advice
Co-located Collaborative Information Visualization

InfoVis
Data Representation
Data Presentation
Data Interaction
Cognition

CSCW
Co-located Work
Synchronous Work
Single-Display
Small Groups

research scope
High Information Density

Low Information Density

Broad Audience

Specific Audience

Map Navigation

Museum Exhibit

Collab. Spreadsheet

Research Tool

Shopping Window

Gaming

[Source: The Information Design Handbook]
More Details:
http://www.aviz.fr/~isenberg/

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