The scale problem currently drives much of Computer Science.

Data sets are growing at a faster rate than the human ability to understand them.

Businesses (and sciences) believe that their data sets contains useful information, and they want to get some business (or scientific) value out of these data sets.

For Graph Drawing, there are two facets of the scale problem:

1. **Computational complexity**
   - Efficiency
   - Runtime
   - We need more efficient algorithms

2. **Visual complexity**
   - Effectiveness
   - Readability
   - We need better ways to untangle large graphs

Graph Drawing has proposed three approaches to the scale problem:

1. **Use 3D**: spread the data over a third dimension
2. **Use interaction**: spread the data over time
3. **Use clustering**: view an abstraction of the data

The classical graph drawing pipeline:

- Data analysis
- Graph visualization
- Picture

Action/decision

the real world
In practice, many iterations of data analysis, visualization, and picture interaction are required.

**Interaction flow**
1. The human looks at key frame $F_i$.
2. The human thinks.
3. The human clicks on something.
4. System computes new key frame $F_{i+1}$.
5. System computes in-betweening animation from key frame $F_i$ to key frame $F_{i+1}$.
6. System displays animated transition from $F_i$ to $F_{i+1}$.
7. $i++$
8. Go to 1.

Graph drawing algorithms need to be designed with interaction flow in mind.

**Interaction can solve both problems:**

**Computational complexity:**
- The layout is only computed for the key frame (a relatively small graph)
- The "user think time" can be used for computation

**Visual complexity:**
- At any one time, only a small graph is on the screen

**Interaction also raises some problems:**

**Cognitive complexity:**
- The user must remember stuff from one key frame to the next
  - "mental map" problem

Graph Drawing has proposed three approaches to the scale problem:

1. **Use 3D**: spread the data over a third dimension
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*A clustered graph $C=(G,T)$ consists of*

- a classical graph $G$, and
- a tree $T$

*such that the leaves of the tree $T$ are the vertices of $G$.*

*The tree $T$ defines a clustering of the vertices of $G.*
- We can only draw a part of a huge graph at a time.

- What part shall we draw?
  - A précis: a graph formed from an antichain in the cluster tree.

- A précis forms an abstraction of the data set.

- A précis is a graph, and can be drawn with the usual graph drawing algorithms.
Drill down

• The basic human interaction with a clustered graph is drill down:
  – “Open” a node to see what it contains, that is, replace a node in the antichain with its children.

• Also, we need drill-up:
  – “Close” a set of nodes to make the picture simpler
    – i.e., replace a set of siblings in the antichain with their parent

• Note: In practical systems
  – the human performs drill-down
  – the system performs drill-up

Clustered graph drawing pipeline

Data → Clustered Graph → Picture

Drill down interaction

• For interaction:
  – “Drill down” on node X changes the size of X
  – “Drill up” should be performed by the system, not by the user
  – Nodes must move to accommodate change in size of node X
  – The new picture must be nice in the usual graph drawing sense
  – The mental map must be preserved:
    • Preserve orthogonal ordering
    • Preserve proximity
    • Preserve topology

Homework

Draw the following social network:
  – Isabella likes Chloe, Jack, and William.
  – Chloe likes Mia and Charlotte.
  – Jack likes Isabella, William, Olivia, Mia, Joshua, and Charlotte.
  – William only likes Chloe, he loves her a lot!
  – Olivia likes Chloe, Mia, and Lachlan; she prefers Chloe to Mia and Lachlan.
  – Mia likes Jack, Joshua, Charlotte, William, and Isabella.
  – Joshua and Isabella and Jack.
  – Charlotte likes William, Olivia, and Jack.
  – Lachlan only likes Olivia.
  – Isabella, Chloe, Lachlan, Olivia and William are students.
  – Mia, Charlotte and Joshua work full time for IBM.
  – Jack is unemployed.
  – Isabella, Chloe, Mia, Charlotte, and Olivia are female.
  – Jack, William, Joshua and Lachlan are male.