

# **COMP5048**

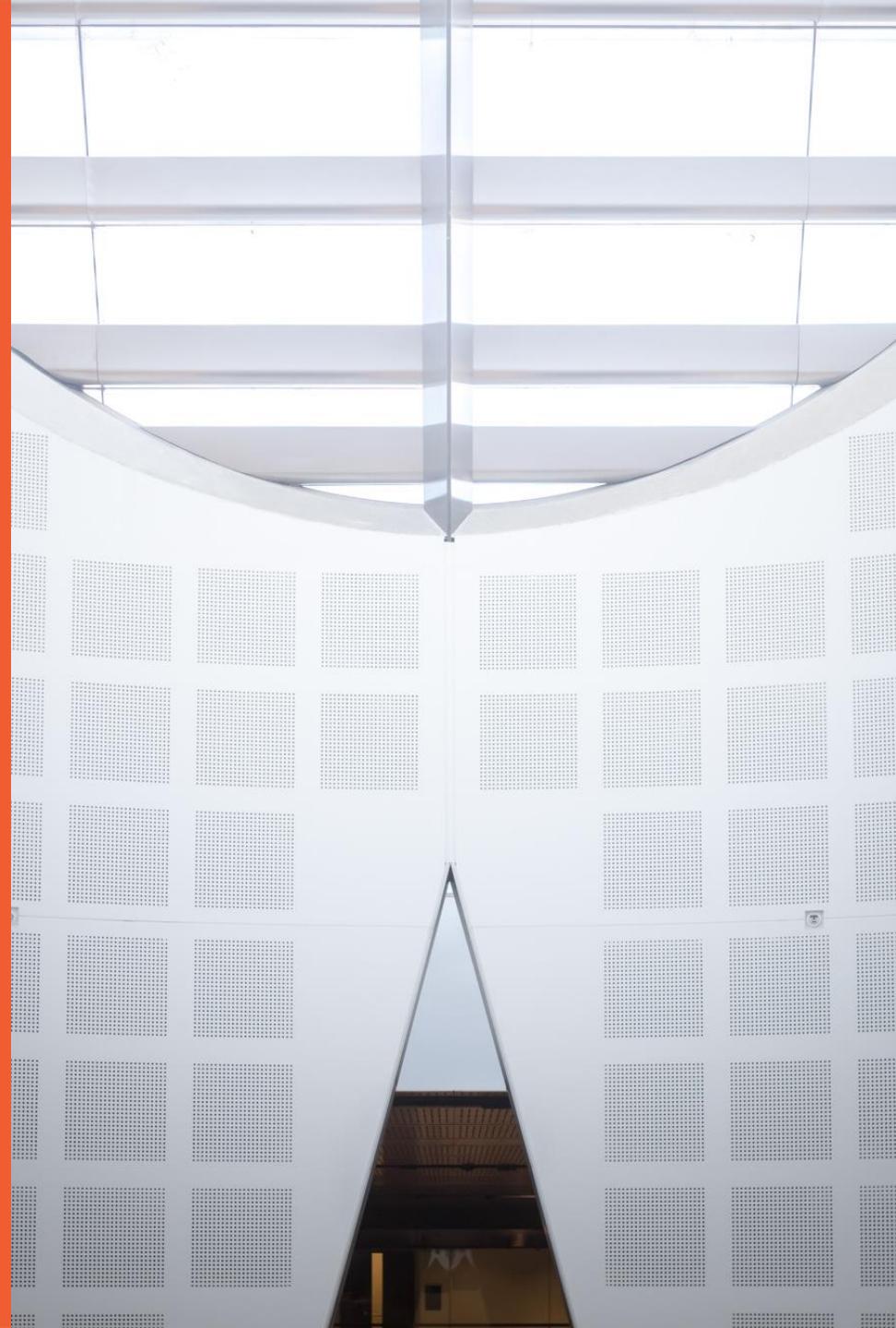
## **Visual Analytics**

### **Week 1: Introduction**

**Professor Seokhee Hong**  
**School of Information Technologies**



THE UNIVERSITY OF  
**SYDNEY**



# Copyright warning

**COMMONWEALTH OF AUSTRALIA**

**Copyright Regulations 1969**

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# Acknowledgement of Country

*Before we begin the proceedings, I would like to acknowledge and pay respect to the traditional owners of the land on which we meet; the Gadigal people of the Eora Nation. It is upon their ancestral lands that the University of Sydney is built.*

*As we share our own knowledge, teaching, learning and research practices within this university may we also pay respect to the knowledge embedded forever within the Aboriginal Custodianship of Country.*

## Content:

- 1. COMP5048 Course Outline**
- 2. Visual Analytics**
- 3. Information Visualisation**
- 4. Graph Drawing**

# **1. COMP5048 Course Outline**

- **Lectures: Thursday 6-8pm**

- **New Law School LT 101 Auditorium**
- **Coordinator/Lecturer: Prof. Seokhee Hong  
(seokhee.hong@sydney.edu.au)**

- **Tutorial: TUE/WED 5-6pm, THU 8-9pm (week 2-9)**

- **TA:**  
**Niku Gorji <niku.gorji@sydney.edu.au>**  
**Amyra Meidiana <amei2916@uni.sydney.edu.au>**
- **Tutors:**  
**Jialu Chen <jialuchen.personal@gmail.com>**  
**Jingming Hu <jihu2855@uni.sydney.edu.au>**  
**Anirudh Sharma <asha9679@uni.sydney.edu.au>**  
**Supraja Sridharan <rssupraja6@gmail.com>**  
**Marnijati Torkel <mtor0581@uni.sydney.edu.au>**

# COMP5048 Visual Analytics (CUSP)

- **Visual Analytics** aims to facilitate the data analytics process using Information Visualisation.
- Information Visualisation aims to make good pictures of abstract information, such as stock prices, health data, social networks, and software diagrams.
- The challenge for Visual Analytics is to design and implement effective Visualisation methods that produce geometric representation of complex data so that data analysts can carry out critical decision making.
- This unit will provide Visualisation techniques and fundamental algorithms to achieve good visualisation of abstract information.
- It will also provide opportunities for academic research and developing new methods for Visual Analytic methods.

# Learning Outcomes (CUSP)

## Design (Level 4)

1. Be able to select appropriate visual variables, space utilisation methods to depict complex data
2. Be able to select, apply and modify visualisation methods suited to a given problem domain in order to facilitate data analytic process through visual inspection.

## Engineering/IT Specialisation (Level 4)

1. Understanding of basic computational concepts, techniques and algorithms to produce good visualisation of abstract data
2. Understanding of the basic HCI principles, which influence the production of good/effective visualisation
3. Experience academic research in Visual Analytics

# Assumed Knowledge

- Data Structures:
  - trees, graphs
  - Array, Adjacency list, matrix representation
- Algorithms:
  - Big O notation
  - Divide and Conquer Algorithm
  - Tree traversal, graph traversal, shortest path
- Programming Skills: Java, C++, Python

# Assessment

- **Homework (10%): individual**
  - **Week 2-9 (tutorial exercise) THU 5pm**
- **Assignment 1 (10%) : individual**
  - **Week 7 THU 5pm**
- **Assignment 2 (30%): Group work (6 students)**
  - **Programming assignment**
  - **Initial Report (5%): Week 8 THU 5pm**
  - **System Demo/Presentation (10%): Week 10 THU 5pm  
(Week 10-12: 6-9pm)**
  - **Final report (15%): Week 13 THU 5pm**
- **Exam (50%): student must achieve at least 40% in the written examination**

- **Tutorial: TUE/WED 5-6pm, THU 8-9pm (week 2-9)**

- **Brief Introduction/exercise using tools**
  - Tableau
  - D3
  - Gephi
  - Yed
  - NetworkX
  - R
- ***Do your homework before you attend tutorial  
(download tools on your own laptop)***
- **Attend tutorial, if you have questions/difficulties**
- **Submit your tutorial exercise (1 mark)**
- **Bonus 1 mark (new data, new layout etc)**

# **Topics Covered: Week 1-8**

**Approximate schedule: *topics are subject to change***

- Week 1: Introduction**
- Week 2: Visualisation of Complex Data**
- Week 3: Visualisation of Relational Data I**
- Week 4: Visualisation of Relational Data II**
- Week 5: Visualisation of Big Data**
- Week 6: Visualisation of Dynamic Data**
- Week 7: Visual Analytic System**
- Week 8: Human Perception, Color**

# **Topics Covered: Week 9-13**

**Approximate schedule: *topics are subject to change***

- **Week 9: Evaluation Methods**
- **Week 10: VA System Presentation I**
- **Week 11: VA System Presentation II**
- **Week 12: VA System Presentation III**
- **Week 13 : Review**

# References

- Giuseppe Di Battista, Peter Eades, Roberto Tamassia, Ioannis G. Tollis, "Graph Drawing: Algorithms for the Visualization of Graphs", Prentice-Hall, 1999.
- Tamara Munzner, Visualization Analysis and Design. CRC Press, 2014.
- Information Visualization : Perception for Design, Colin Ware, Morgan Kaufmann, 2012.
- *Illuminating the Path: The Research and Development Agenda for Visual Analytics* <http://nvac.pnl.gov/agenda.stm>
- Conference Proceedings: IEEE InfoVis, VAST, EuroVis, PacificVis, GD
- Journals:
  - IEEE Transactions on Visualization and Computer Graphics,  
<http://www.computer.org/tvcg/>

# COMP5048: resources

- eLearning
  - Canvas
  - Login using Unikey and password
  - Link to CUSP
    - Official schedule, list of learning outcomes, etc
  - Copies of lecture slides
  - Lecture videos
    - We intend to record the lectures, but sometimes the technology is not reliable
  - ***Submit official assignment work here;***
  - See your grades; etc
  - Tutorial material
  - References
  - Link to USYD policy

# General Expectations

- Students attend scheduled classes/tutorials, and devote an extra 5-8 hrs per week
  - watch videos if not able to attend lectures
  - doing assessments/homework
  - reviewing for classes
  - integrating the ideas
  - practice/exercise tools
- Students are responsible learners
  - Check eLearning site at least once a week!
  - Notify academics whenever there are difficulties
  - Know and adhere to University policies
  - Participate in classes, constructively

# **IMPORTANT:**

## **POLICY RELATING TO ACADEMIC DISHONESTY AND PLAGIARISM**

- All students must submit a cover sheet for all assessment work that declares that the work is original and not plagiarised from the work of others.

# **USYD/SIT Policies**

- You are required to carefully read the policies on
  - Academic Honesty and Plagiarism
  - Special consideration due to illness and misadventure
- See the policies page of the faculty website at  
<http://sydney.edu.au/engineering/student-policies/> for information regarding university policies and local provisions and procedures within the Faculty of Engineering and Information Technologies.

# Special Consideration (University policy)

- If your performance on assessments is affected by *illness or misadventure*
- Follow proper bureaucratic procedures
  - Have professional *practitioner sign special USyd form*
  - Submit application for special consideration online, upload scans
  - <http://sydney.edu.au/students/special-consideration-and-arrangements.html>
  - If request is denied, consult coordinator immediately
- Notify coordinator by email as soon as *anything begins to go wrong*
- There is a similar process if you need special arrangements eg for religious observance, military service, representative sports

# Late assessments

- For assignments (If you have not been granted special consideration or arrangements)
  - A penalty of 20% of the available marks will be taken, per day (or part) late
- *Eg your work would have scored 60% and is 1 hour late*
  - *you get 40%*
- *Eg your work would have scored 70% and is 28 hours late*
  - *you get 30%*
- Get something done early and submit it early; you can try to improve it and resubmit if there is time before the deadline

# Academic honesty

- Please read the University policy on Academic Honesty carefully, from

<http://sydney.edu.au/students/academic-integrity.html>

“As a student of the University, you are responsible for taking part in your education in an honest and authentic manner.”

- There is a process and a centralized University system and database
- Offenses include:
  - Plagiarism – when you copy from another student, website or other source. This includes copying the whole assignment or only a part of it.
  - Academic dishonesty – when you make your work available to another student to copy (the whole assignment or a part of it). There are other examples of academic dishonesty.
  - Misconduct - when you engage another person to complete your assignment (or a part of it), for payment or not. This is a very serious matter and the Policy requires that your case is forwarded to the University Registrar for investigation.

# Penalties

- The penalties are **severe** and include:
  - 1) a permanent record of academic dishonesty, plagiarism and misconduct in the University database and on your student file
  - 2) mark deduction, ranging from 0 for the assignment to Fail for the unit
  - 3) expulsion from the University and (for international students) cancelling of your student visa

**Be smart and don't risk your future by engaging in plagiarism and academic dishonesty!**

# Detection

- We will use the similarity detection software TurnItIn and MOSS to compare your assignments with these of other students (current and previous) and the Internet
  - Turnitin is for text documents: [http://www.turnitin.com/en\\_us/higher-education](http://www.turnitin.com/en_us/higher-education)
  - MOSS is for programming code:  
<https://theory.stanford.edu/~aiken/moss/>
- These tools are **extremely good!**
- If you cheat, the chances you will be caught are very high.

# **WHS INDUCTION**

**School of Information Technologies**

# General Housekeeping – Use of Labs

- Keep work area clean and orderly
- Remove trip hazards around desk area
- No food and drink near machines
- No smoking permitted within University buildings
- Do not unplug or move equipment without permission



# EMERGENCIES – Be prepared



▪ [www.sydney.edu.au/whs/emergency](http://www.sydney.edu.au/whs/emergency)



THE UNIVERSITY OF  
SYDNEY

SAFETY HEALTH & WELLBEING

SAFETY HEALTH & WELLBEING UNIVERSITY HOME STAFF INTRANET CONTACTS

Policy & strategy Responsibilities Managing WHS A-Z info Health and wellbeing Consultation Incident/hazard reporting Workers comp. Emergency

You are here: Home / WHS / Emergency

**EMERGENCY**

- [What to do in an emergency](#)
- [First aid](#)
- [Incident & accident reporting](#)
- [Chief building wardens](#)
- [Emergency management](#)
- [Building emergency procedures](#)
- [Handling of suspicious packages](#)
- [Chem Alert \(MSDS\)](#)
- [Mercury spills](#)

**WHAT TO DO IN AN EMERGENCY**

Emergencies can occur at any time, and can arise from a number of causes including fire, medical emergencies, chemical spills, gas leaks, bomb threats and physical threats. The first priority in any emergency situation is the safety of all people who may be in danger.

- [Be prepared](#)
- [Fire alarms](#)
- [Emergency response](#)
- [Medical emergencies](#)
- [People with disabilities](#)
- [Hazardous material incidents](#)
- [Gas leaks](#)
- [Phone threats](#)
- [Unattended bags or other suspicious items](#)
- [Emergency lockdown](#)
- [Personal safety on campus](#)
- [Personal threats](#)
- [Suspicious behaviour](#)

**Be prepared**

**SAFETY HEALTH & WELLBEING**

**EMERGENCY CONTACT NUMBERS**

**POLICE, FIRE, AMBULANCE:**

| Dial **0-000** from a University phone; if you are calling from an external line or mobile phone, dial **000**. Be prepared to give your name and location, and details of the emergency.

**OTHER USEFUL NUMBERS**

| **University Security Service:** 9351-3333  
This is an emergency number only.

| **Chief fire wardens**

| **Nominated first aid officers**

# **EMERGENCIES**

**WHERE IS YOUR  
CLOSEST SAFE EXIT ?**

# EMERGENCIES

## Evacuation Procedures

### ALARMS



**BEEP... BEEP...**

Prepare to evacuate

1. Check for any signs of immediate danger.
2. Shut Down equipment / processes.
3. Collect any nearby personal items.



**WHOOP... WHOOP...**

Evacuate the building

1. Follow the **EXIT** exit signs.
2. Escort visitors & those who require assistance.
3. DO NOT use lifts.
4. Proceed to the assembly area.

### EMERGENCY RESPONSE

1. Warn anyone in immediate danger.
2. Fight the fire or contain the emergency, if safe & trained to do so.

If necessary...

3. Close the door, if safe to do so.
4. Activate the **"Break Glass"** Alarm  or 
5. Evacuate via your closest safe exit.  
6. Report the emergency to 0-000 & 9351-3333

# MEDICAL EMERGENCY

- **If a person is seriously ill/injured:**

1. **call an ambulance 0-000**
2. **notify the closest Nominated First Aid Officer**

**If unconscious– send for Automated External Defibrillator (AED) [AED locations](#).**

**NEAREST to SIT Building (J12)**

- Electrical Engineering Building, L2 (ground) near lifts
- Seymour Centre, left of box office
- Carried by all Security Patrol vehicles

3. **call Security - 9351-3333**
4. **Facilitate the arrival of Ambulance Staff (via Security)**



## Nearest Medical Facility

University Health Service in Level 3, Wentworth Building

## First Aid kit – SIT Building (J12)

- kitchen area adjacent to Lab 110

# School of IT Safety Contacts



## ▪FIRST AID OFFICERS

Name: Will Calleja

Location: 1 West

Phone: 9036 9706

Name: Katie Yang

Location: 2E-227

Phone: 9351 4918

Orally REPORT all  
INCIDENTS  
& HAZARDS  
to your SUPERVISOR

Undergraduates: to Katie Yang

9351 4918

SIT School Manager: Shari Lee

9351 4158

# Support!

- See <http://sydney.edu.au/campus-life/safety-security.html>
- If you need to report an incident of sexual harassment or assault, or make a complaint about misconduct, or want assistance in any way, call our confidential helpline, **1800 SYD HLP (1800 793 457)**.
- There are a wide range of support services available for students
  - Please make contact, and get help

# **DISABILITY SERVICES**

## **Do you have a disability?**

- You may not think of yourself as having a ‘disability’ but the definition under the **Disability Discrimination Act** is broad and includes temporary or chronic medical conditions, physical or sensory disabilities, psychological conditions and learning disabilities.
- **The types of disabilities we see include:**
  - anxiety, arthritis, asthma, asperger's disorder, ADHD, bipolar disorder, broken bones, cancer, cerebral palsy, chronic fatigue syndrome, crohn's disease, cystic fibrosis, depression, diabetes, dyslexia, epilepsy, hearing impairment, learning disability, mobility impairment, multiple sclerosis, post traumatic stress, schizophrenia , vision impairment, and much more.
- **Students needing assistance must register with Disability Services –**
  - it is advisable to do this as early as possible.
- <http://sydney.edu.au/study/academic-support/disability-support.html>

# Other support

- **Learning support**
  - <http://sydney.edu.au/study/academic-support/learning-support.html>
- **International students**
  - <http://sydney.edu.au/study/academic-support/support-for-international-students.html>
- **Aboriginal and Torres Strait Islanders**
  - <http://sydney.edu.au/study/academic-support/aboriginal-and-torres-strait-islander-support.html>
- **Student organization (can represent you in academic appeals etc)**
  - <http://srcusyd.net.au/> or <http://www.supra.net.au/>

# Questions?

## **2. Visual Analytics**

# Visual Analytics

- *the science of analytical reasoning facilitated by visual interactive interfaces*
- especially concerned with *sensemaking* and *reasoning*
- Visual analytics integrates new computational & theory-based tools with innovative interactive techniques and visual representations to enable human-information discourse

## Reference:

***Illuminating the Path: The Research and Development Agenda for Visual Analytics***

<http://nvac.pnl.gov/agenda.stm>

- **Information visualisation amplifying human cognitive capabilities:**
  1. by **increasing cognitive resources**, such as by using a visual resource to expand human working memory,
  2. by **reducing search**, such as by representing a large amount of data in a small space,
  3. by enhancing the **recognition of patterns**, such as when information is organized in space by its time relationships,
  4. by supporting the easy **perceptual inference** of relationships that are otherwise more difficult to induce,
  5. by **perceptual monitoring** of a large number of potential events, and
  6. by providing a **manipulable medium** that, unlike static diagrams, enables the exploration of a space of parameter values.
- **Information visualization, combined with data analysis, can be applied to analytic reasoning to support the sense-making process.**

# Visual Analytics Scope

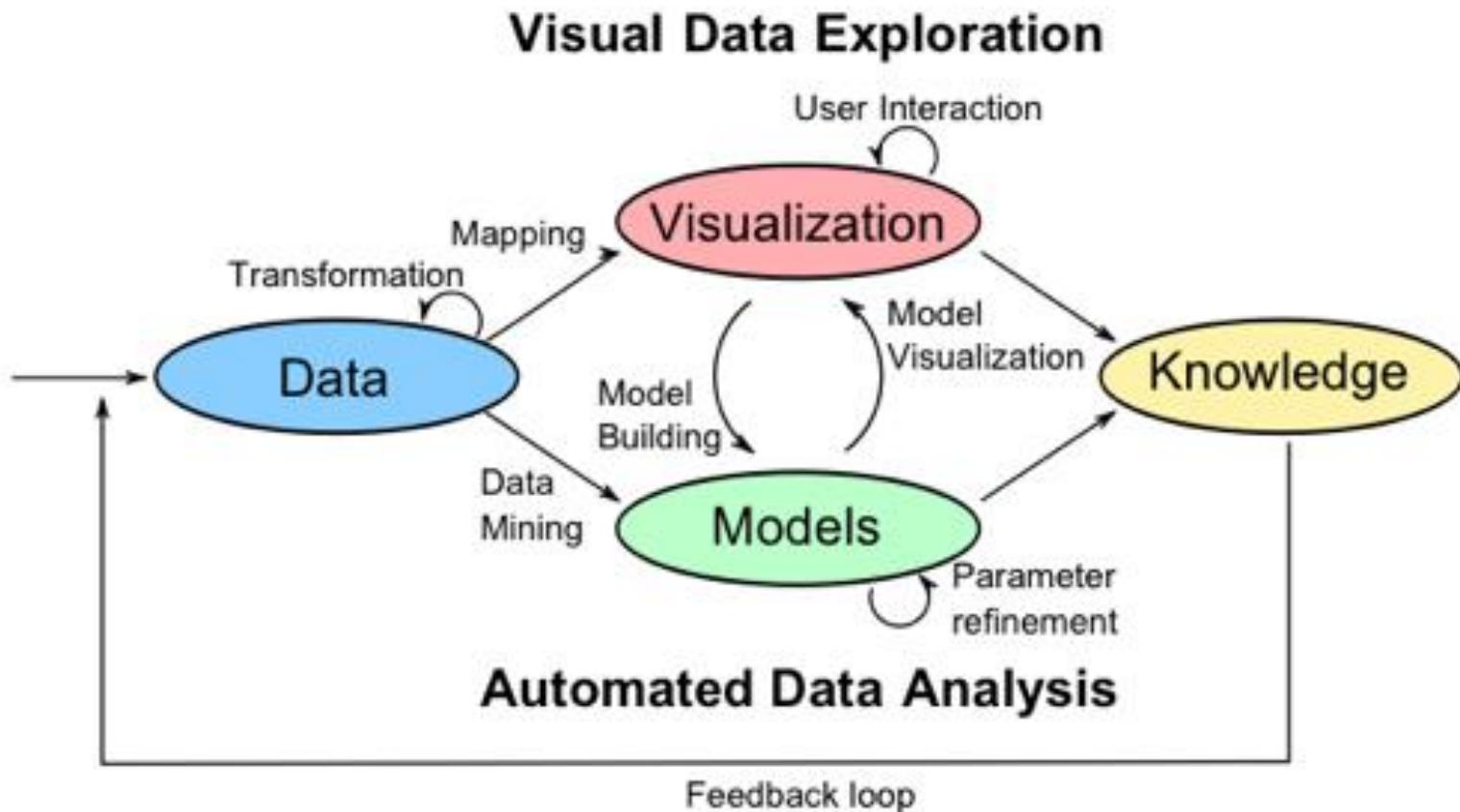


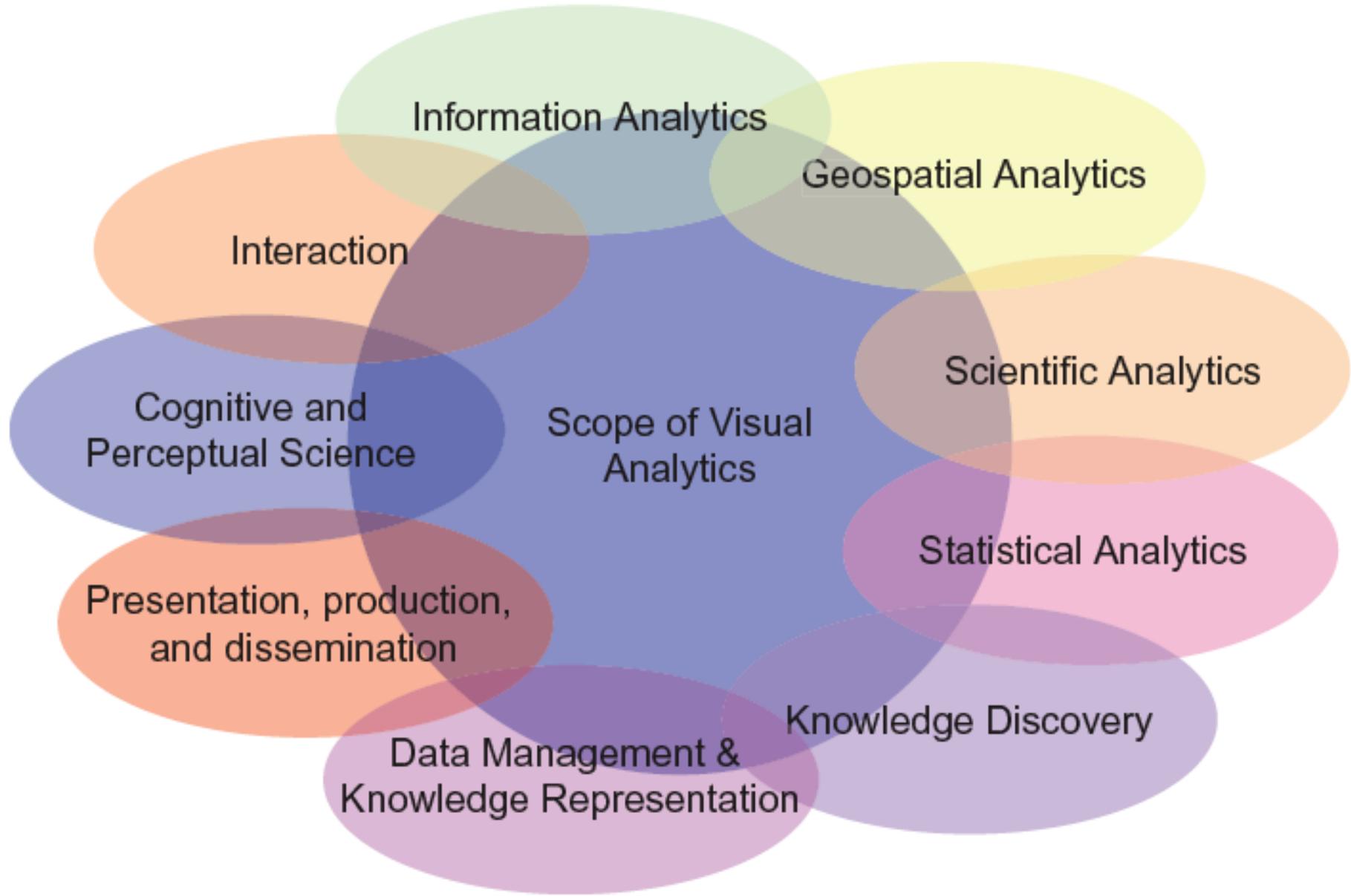
**Scope:** multidisciplinary field that includes:

- 1. Analytical reasoning techniques that enable users to obtain deep insights that directly support assessment, planning, and decision making**
- 2. Data representations and transformations that convert all types of conflicting and dynamic data in ways that support visualization and analysis**
- 3. Visual representations and interaction techniques that take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once**
- 4. Techniques to support production, presentation, and dissemination of the results of an analysis to communicate information in the appropriate context to a variety of audiences.**

- Visual analytics tools must enable diverse analytical tasks:
  1. Understanding past and present situations quickly, as well as the trends and events that have produced current conditions
  2. Identifying possible alternative **futures** and their warning signs
  3. Monitoring current events for **emergence** of warning signs as well as **unexpected** events
  4. Determining indicators of the intent of an action or an individual
  5. Supporting the **decision maker** in times of crisis.
- These tasks will be conducted through a combination of individual and **collaborative analysis**, often under **extreme time pressure**.
- Visual analytics must enable hypothesis-based and scenario-based analytical techniques, providing support for the analyst to reason based on the available evidence
- Visual analytics must facilitate high-quality human judgment with a limited investment of the analysts' time.

# Visual Analytics Framework [Keim]





# Good Visualisation

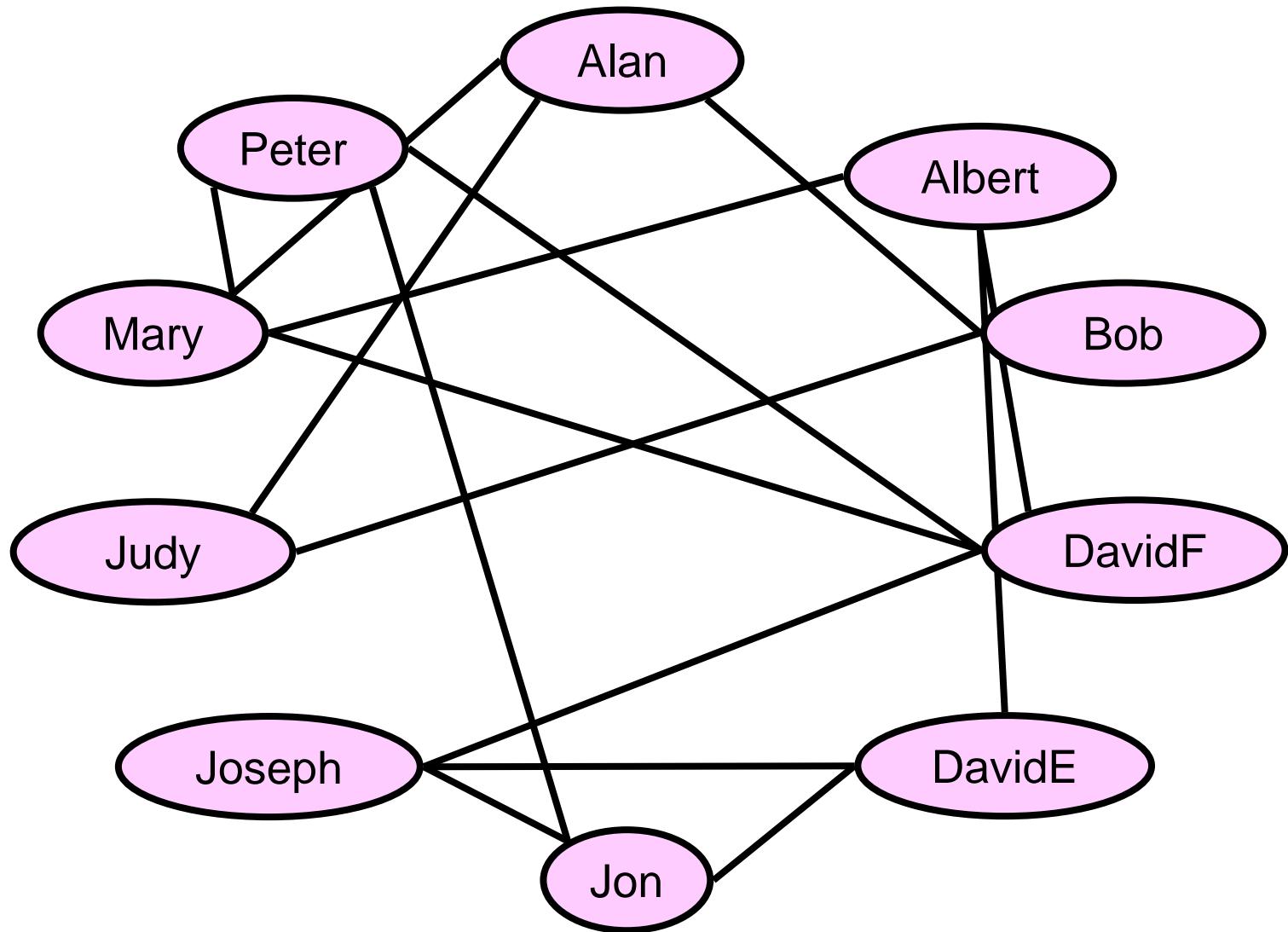
- **Good visualisation** can enable users:
  - to understand the *structure*
  - to discover *new knowledge/insight*
  - to find *regular/abnormal patterns/behavior*
  - to generate/confirm/reject *hypothesis*
  - to confirm *expected* and discover *unexpected*
  - to reveal the hidden *truth*
  - to predict the *future*

# Simple Example: Email Social Networks

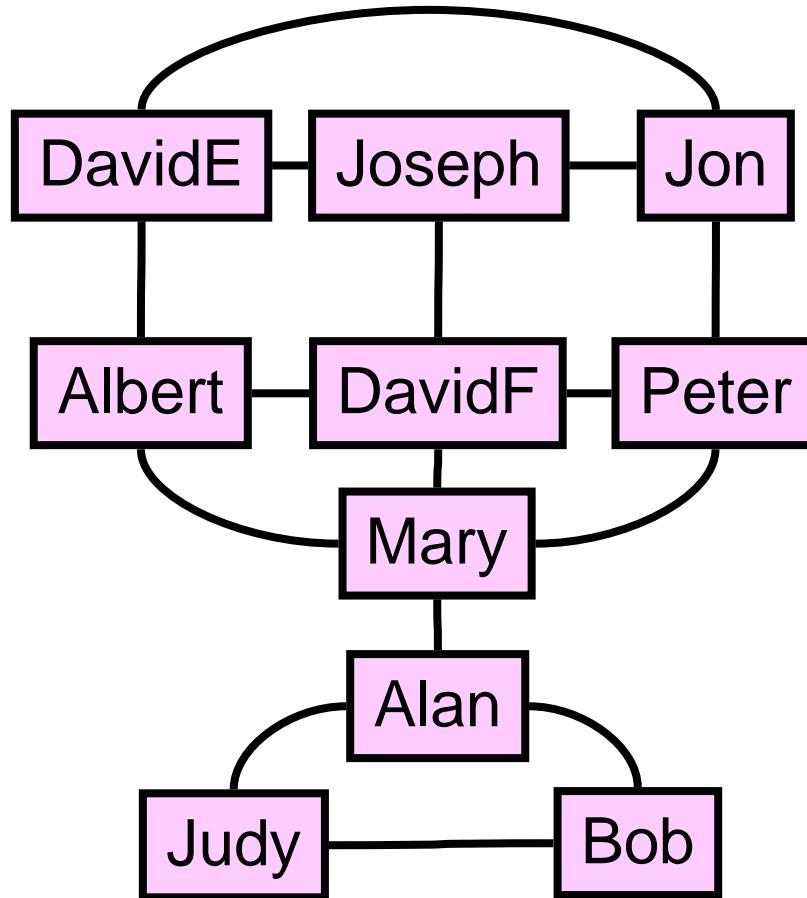
$X$	<i>Email_friends ( X )</i>
Mary	Peter, Albert, DavidF, Alan
Judy	Bob, Alan
Peter	Mary, DavidF, Jon
DavidF	Albert, Joseph, Peter, Mary
Jon	Peter, Joseph, DavidE
DavidE	Jon, Joseph, Albert
Joseph	DavidE, Jon, DavidF
Bob	Judy, Alan
Alan	Bob, Mary, Judy
Albert	DavidF, Mary, DavidE

- The *email\_friends* graph can be derived from email log files.

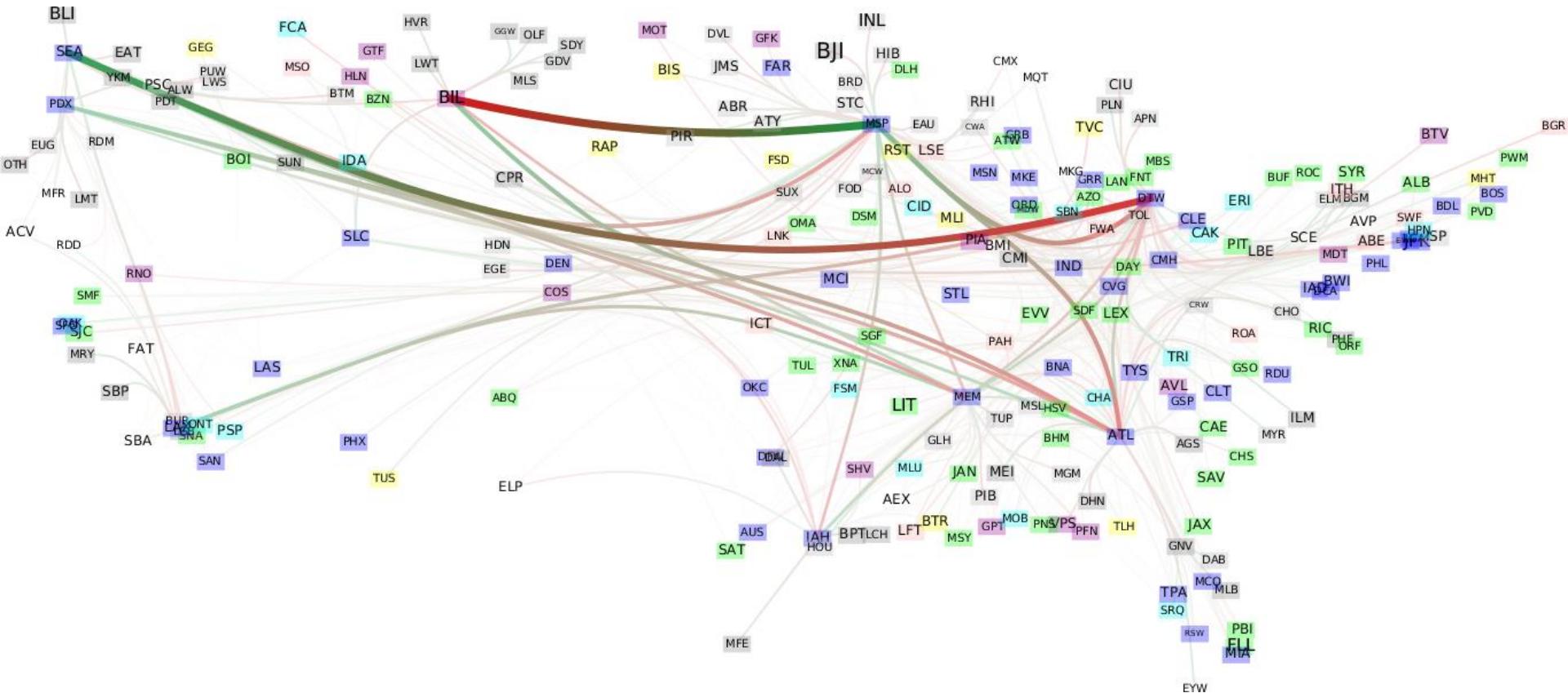
# Visualisation A

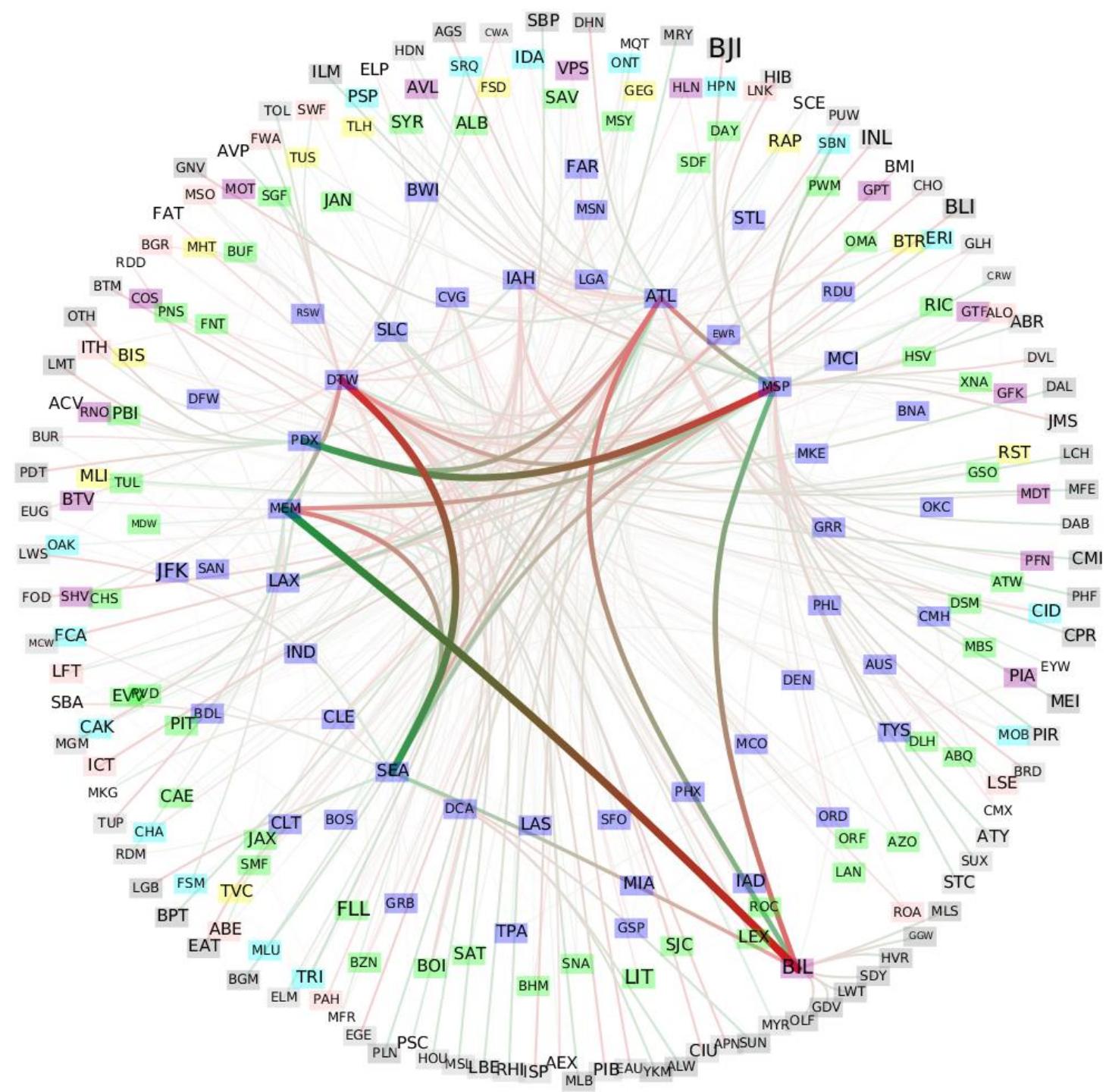


# Visualisation B

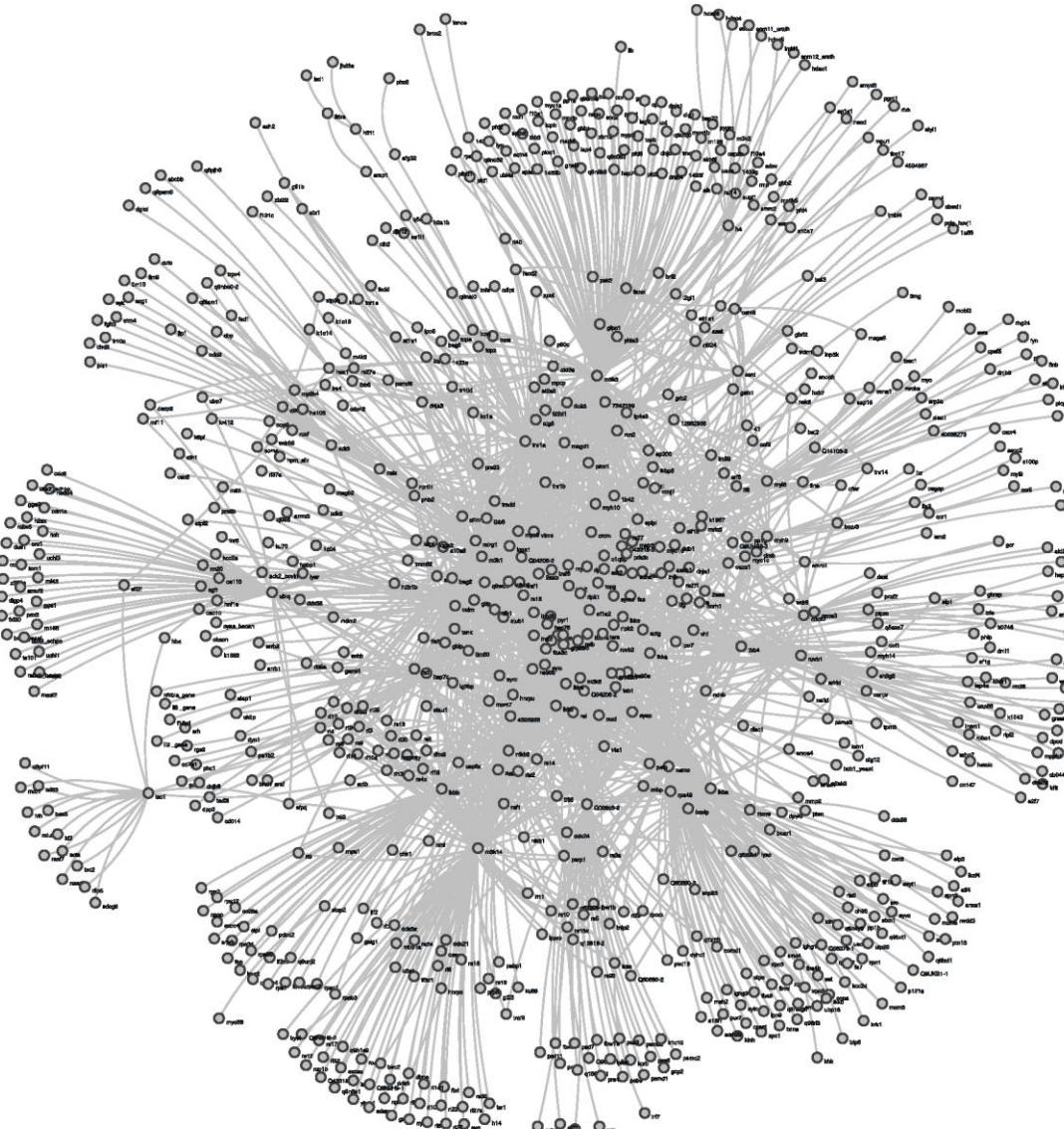


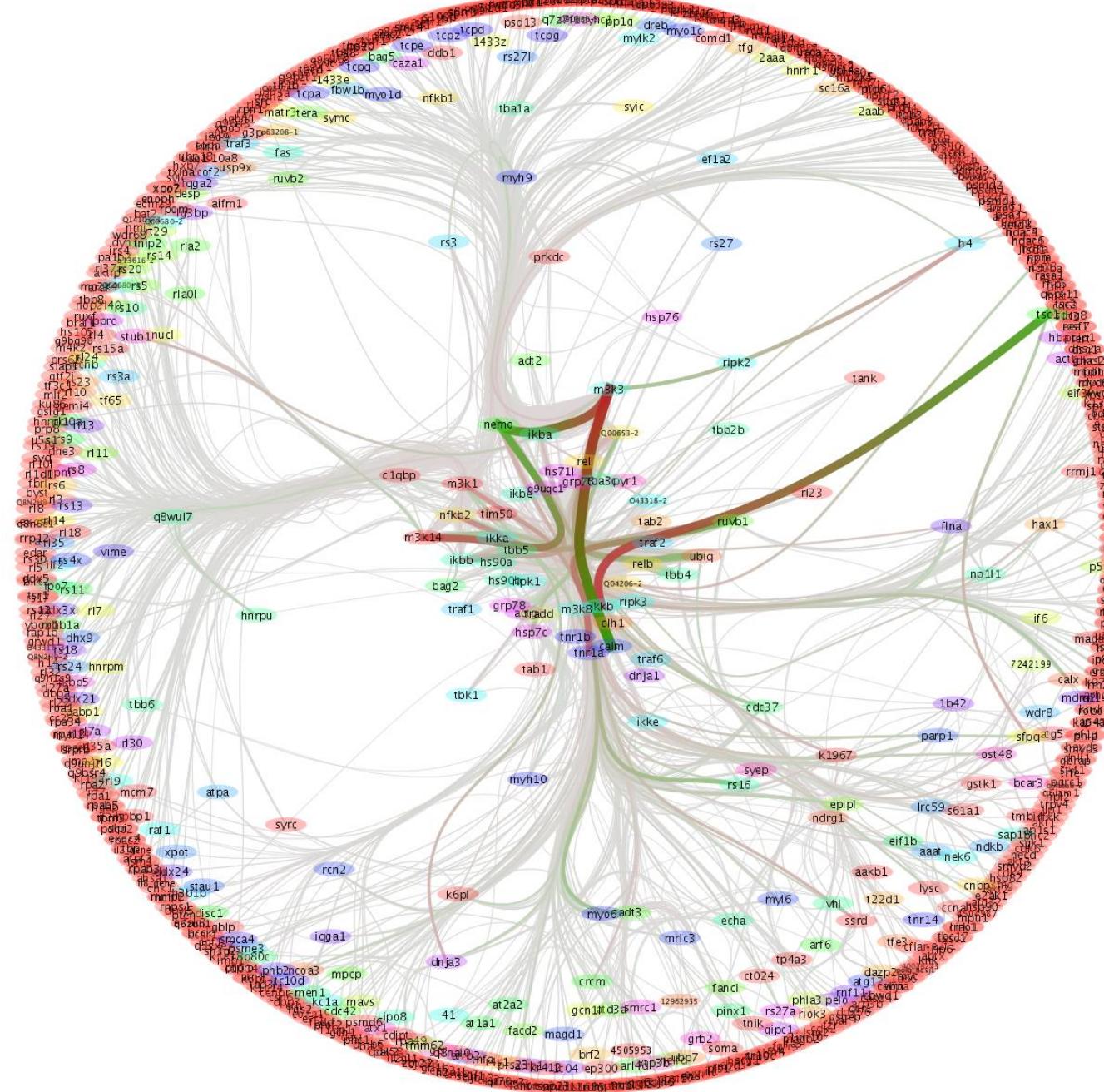
# US Airline Network Traffic Analysis



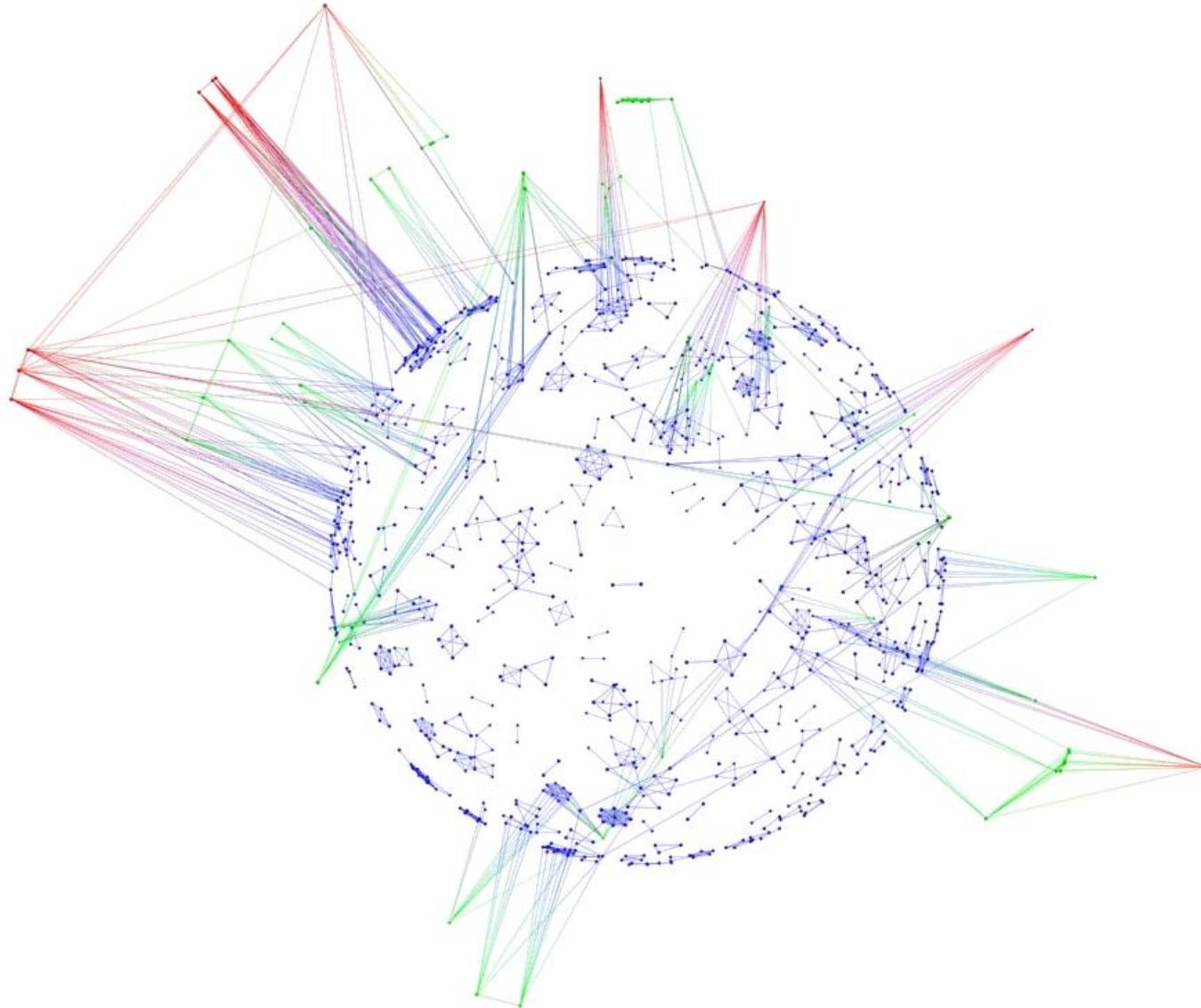


# Protein-Protein Interaction Network



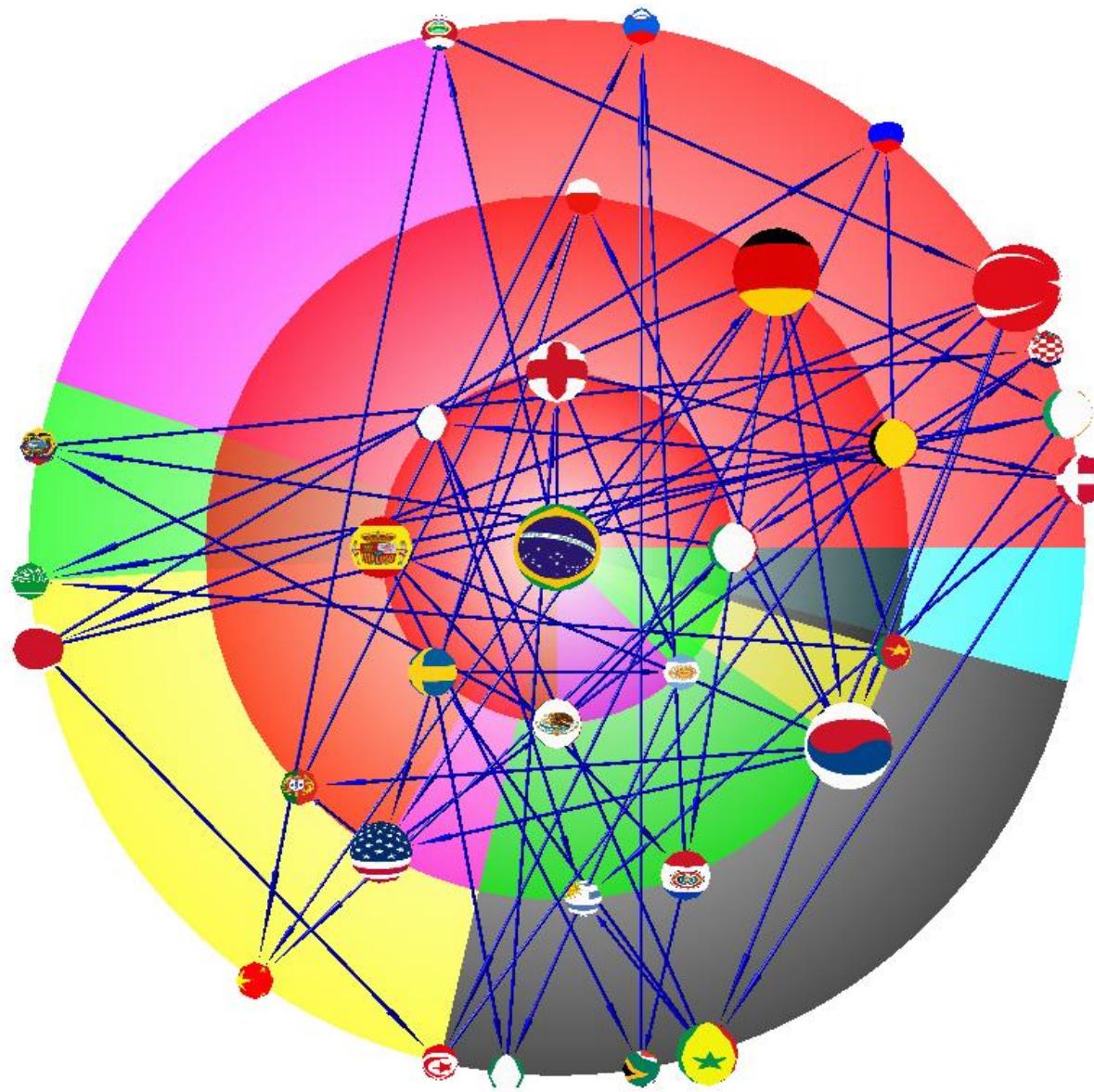


# Scale-free Network: Collaboration Network



Apex: prominent researchers,  $|V|=982$ ,  $|E|=2012$   
Research Empire: research clusters

# World Cup 2002



### **3. Information Visualisation**

# Visualisation

- Visualisation:  
**the use of computer-supported, interactive, visual representations of data to amplify cognition.**
  - **Scientific visualisation:**  
the use of computer-supported, interactive, visual representations of **scientific data** to amplify cognition.
  - **Information visualisation:**  
the use of computer-supported, interactive, visual representations of **abstract data** to amplify cognition.

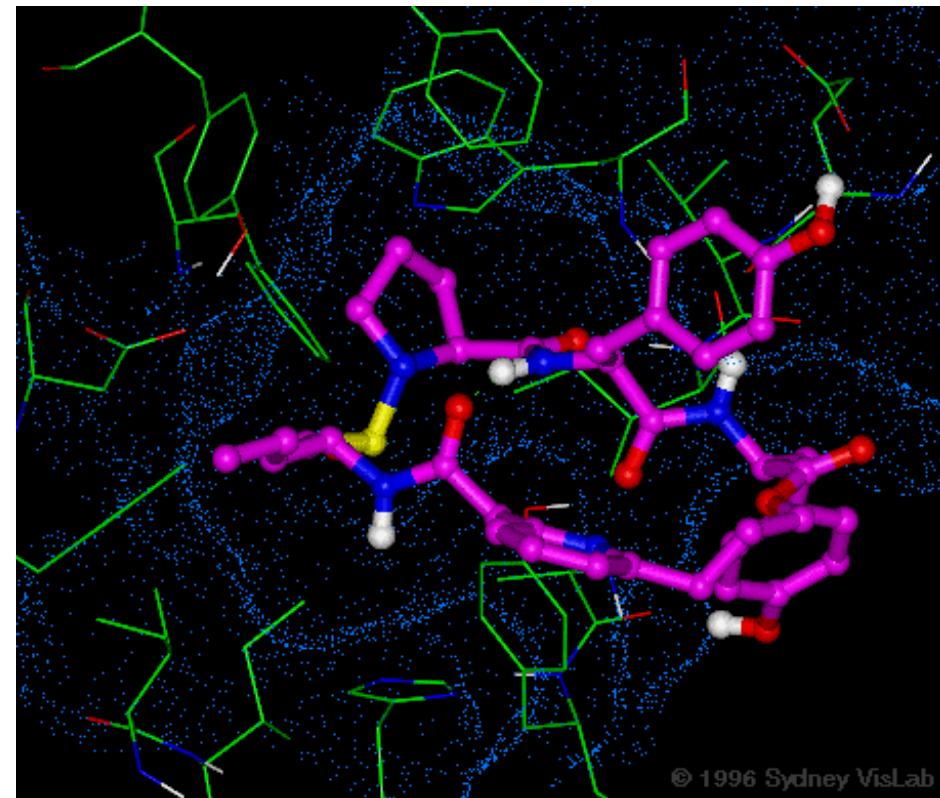
# Scientific Visualisation

## Astrophysics - Astronomy



- Visualisation of the Durham/UKST Galaxy Redshift Survey
- Andrew Ratcliffe,

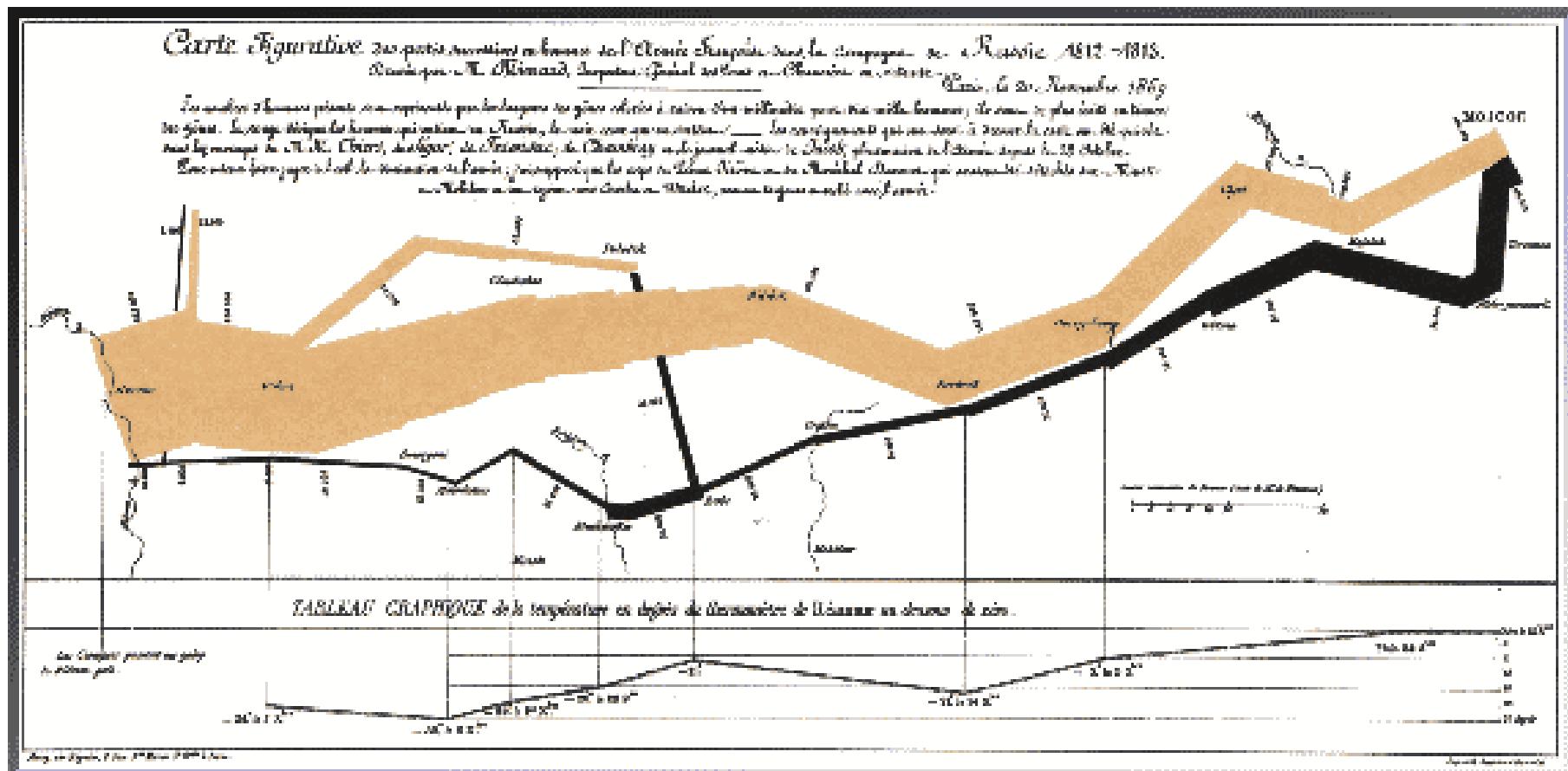
## Chemistry – Biochemistry



- Molecular Modelling of Immunosuppressant Molecules Bound to an Enzyme
- Peter Karuso

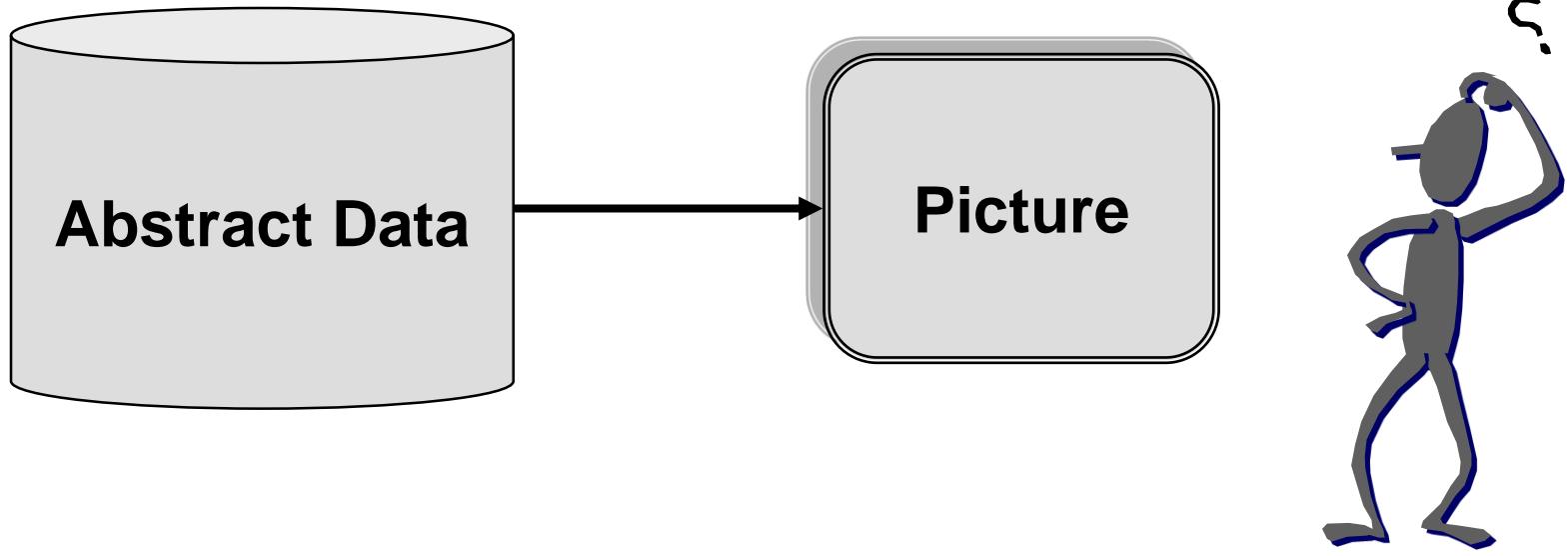
# Information Visualisation

## the loss of Napoleon's army



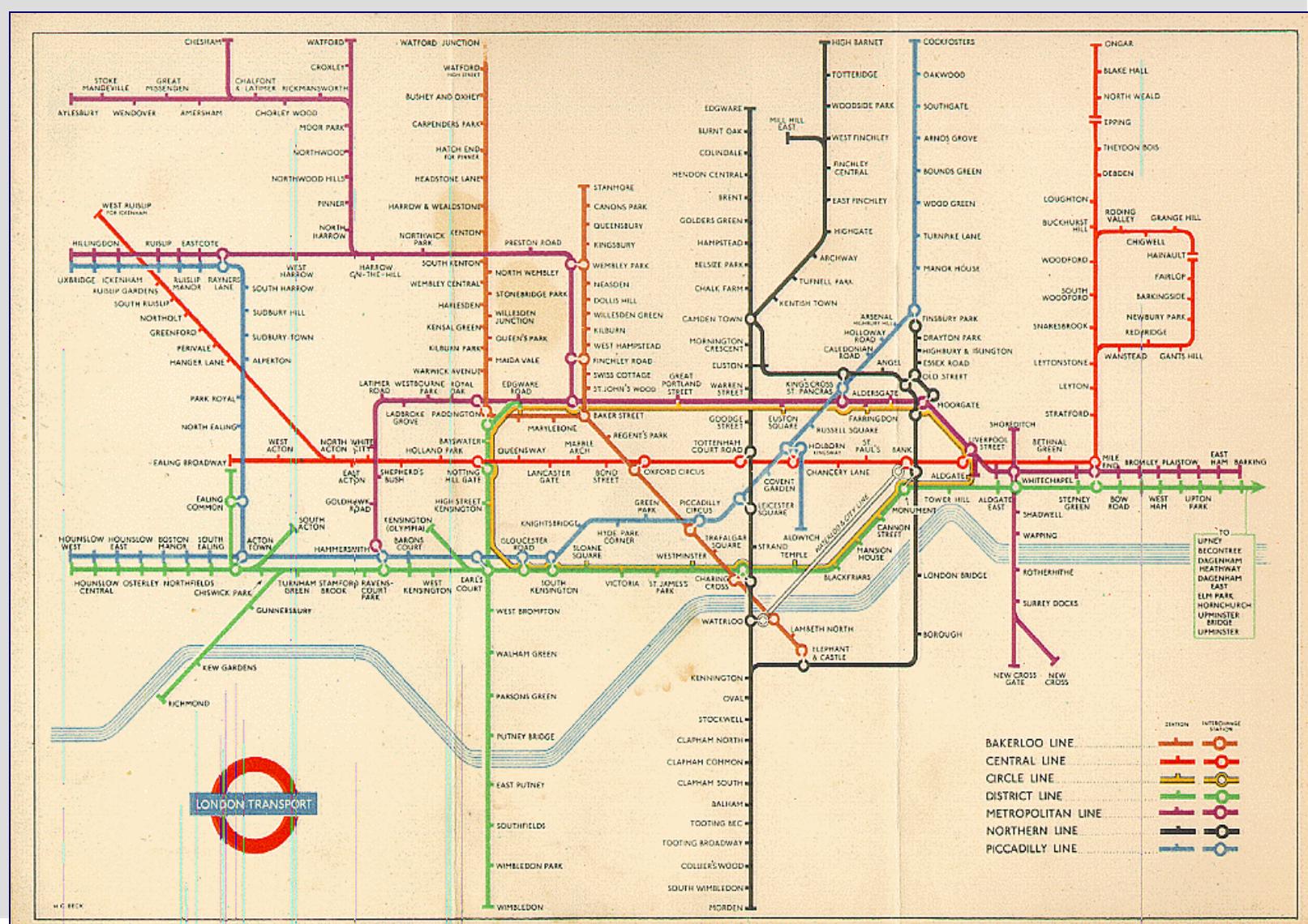
- Edward R. Tufte, The Visual Display of Quantitative Information
- by Charles Joseph Minard (1781-1870)
- Russian-Polish border 422,000 men / Moscow 100,000 men.

# Information Visualisation



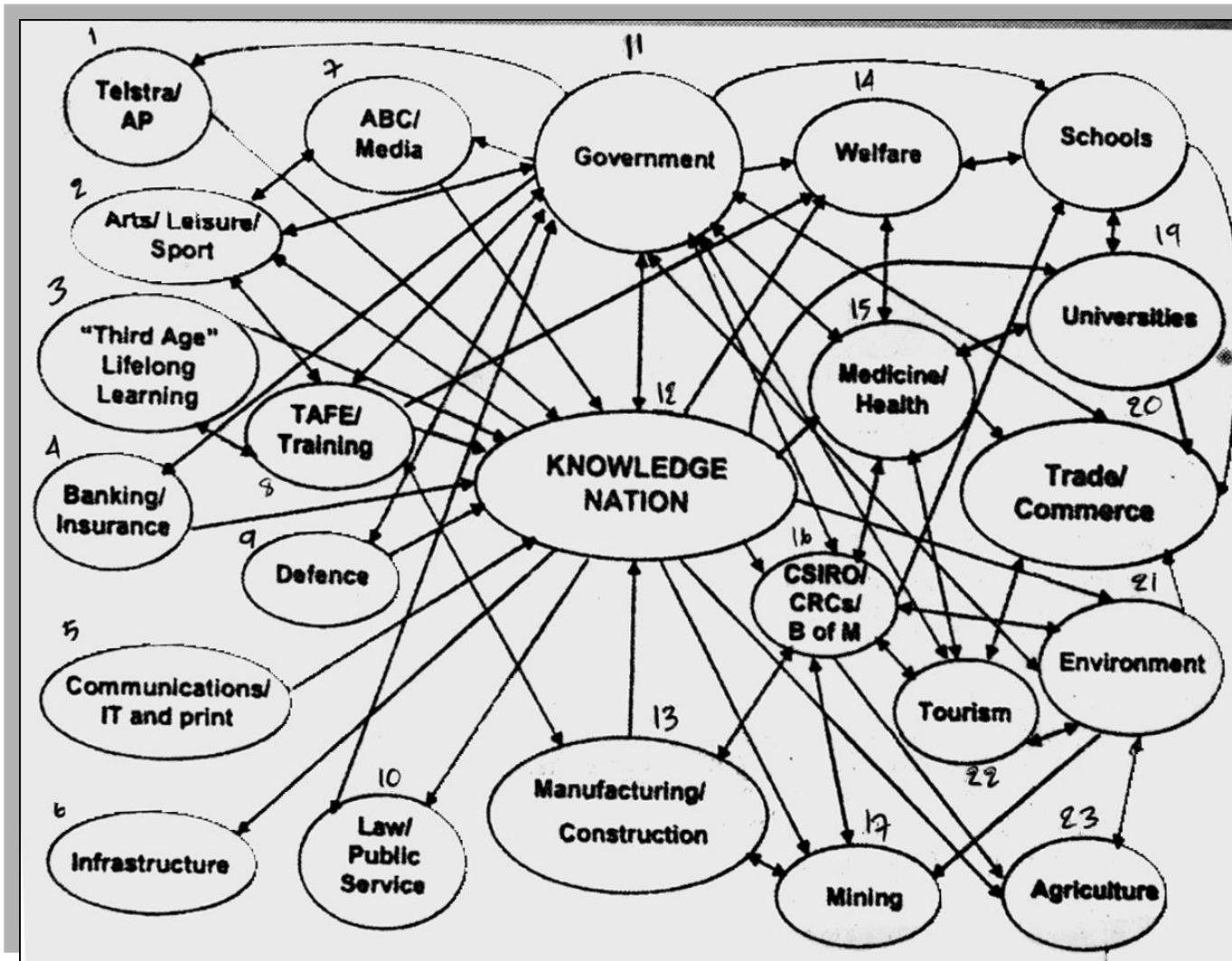
*Information visualisation research aims to make pictures of abstract data so that humans can understand, navigate, and manipulate the data.*

# Good visualisation



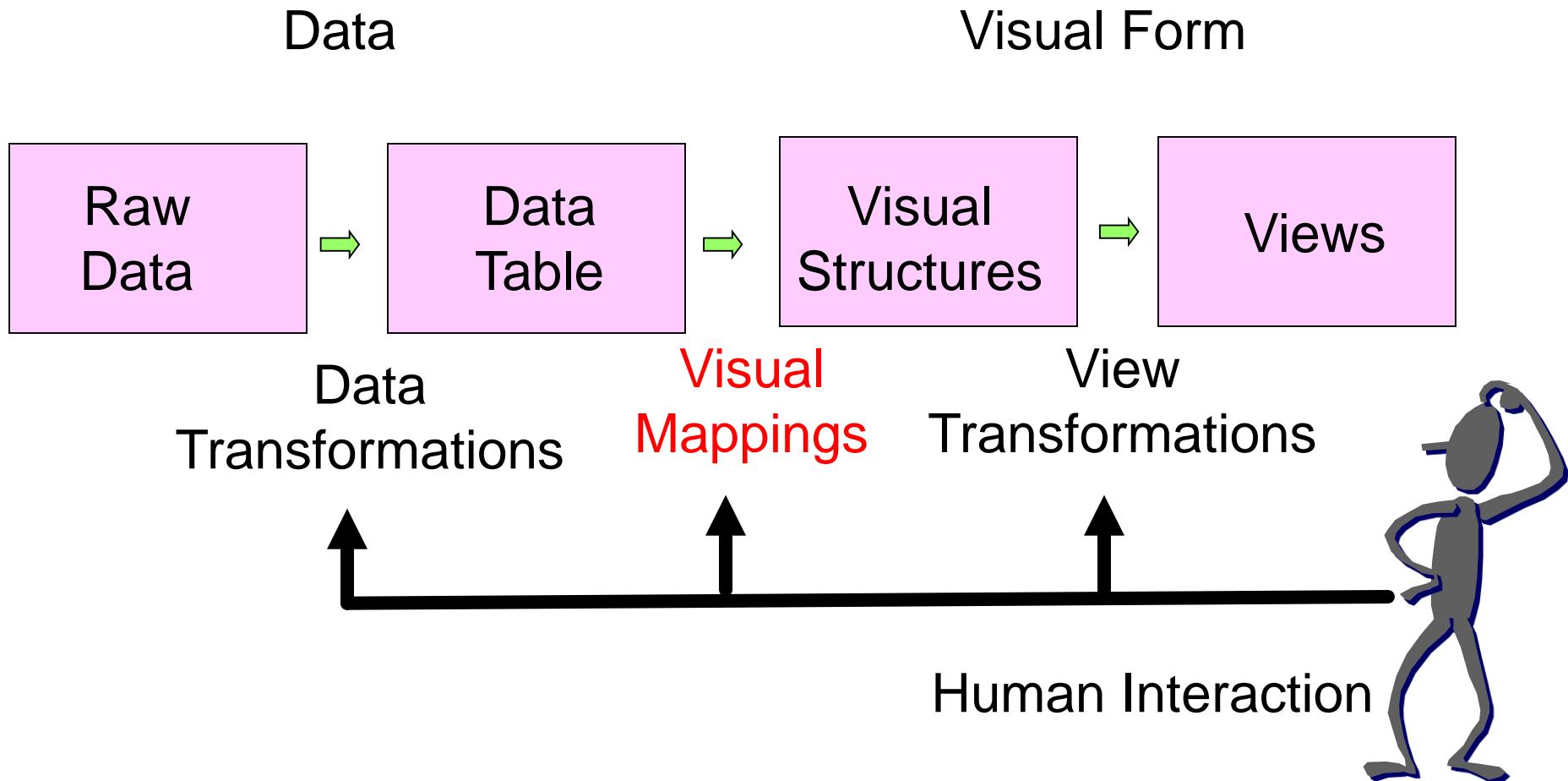
• H. Beck

# Bad visualisation



■ ALP

# Reference Model for Visualisation



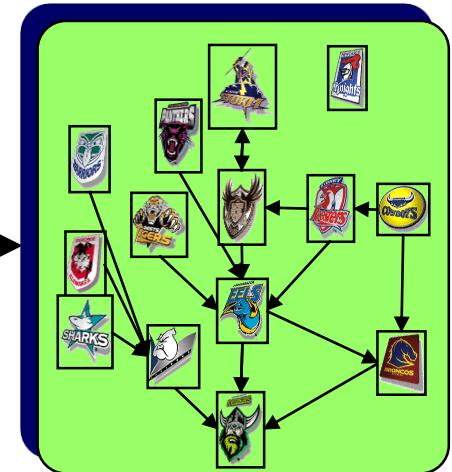
# Visualisation of football transfers



## *Analysis*

- Drew moved from the Panthers to the Eels
  - Miles moved from the Roosters to the Eagles
  - Green moved from the Cowboys to the Roosters
  - O'Hara moved from the Bulldogs to the Raiders

## *Visualisation*

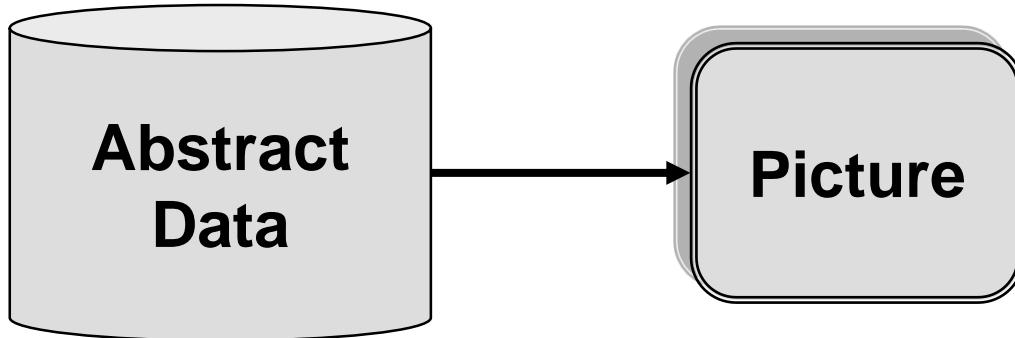


# Data

# Graph

# Picture

# Representation and Techniques



Representation (Metaphor): how to represent the data

Techniques/Algorithms/Methods: how to construct such representation automatically using a computer efficiently and effectively

# Data Types

Table data:

Multi-dimensional/Muti-variate/Multi-attribute Data:

Types of Attributes:

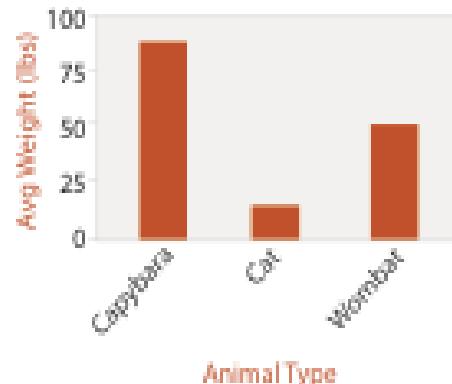
-> Nominal value, categorical value, text, image, time stamps, spatial information etc

eg. Student data =(Degree, Year, Academic records, International/local, Address, Phone number, email)

Graph data:

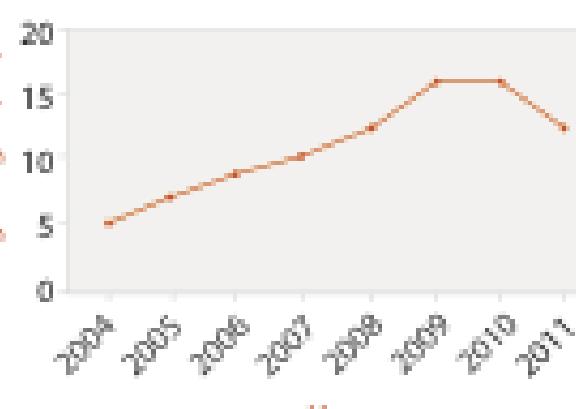
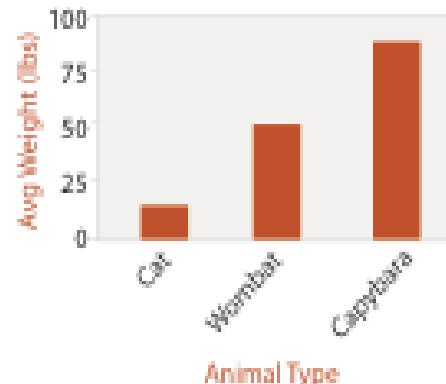
$G=(V, E)$ , V: vertex (node) set , E: edge set

Social network, Twitter, facebook, linked-in etc

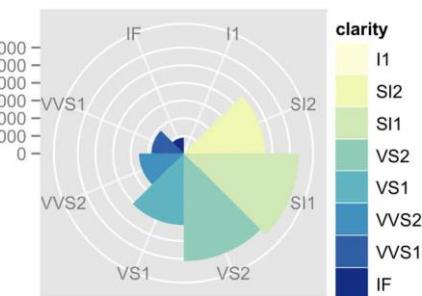


## Bar chart

## Radial bar chart

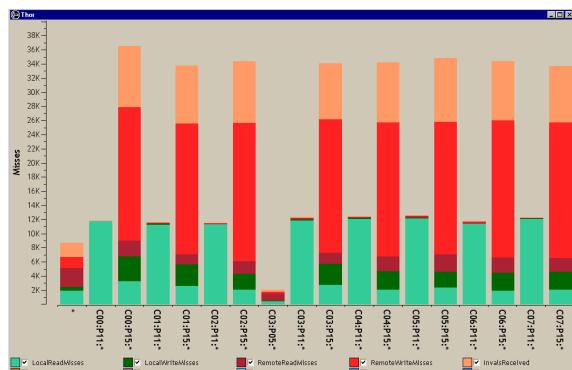


## Line chart



## Polar area chart

# Table Data VIS

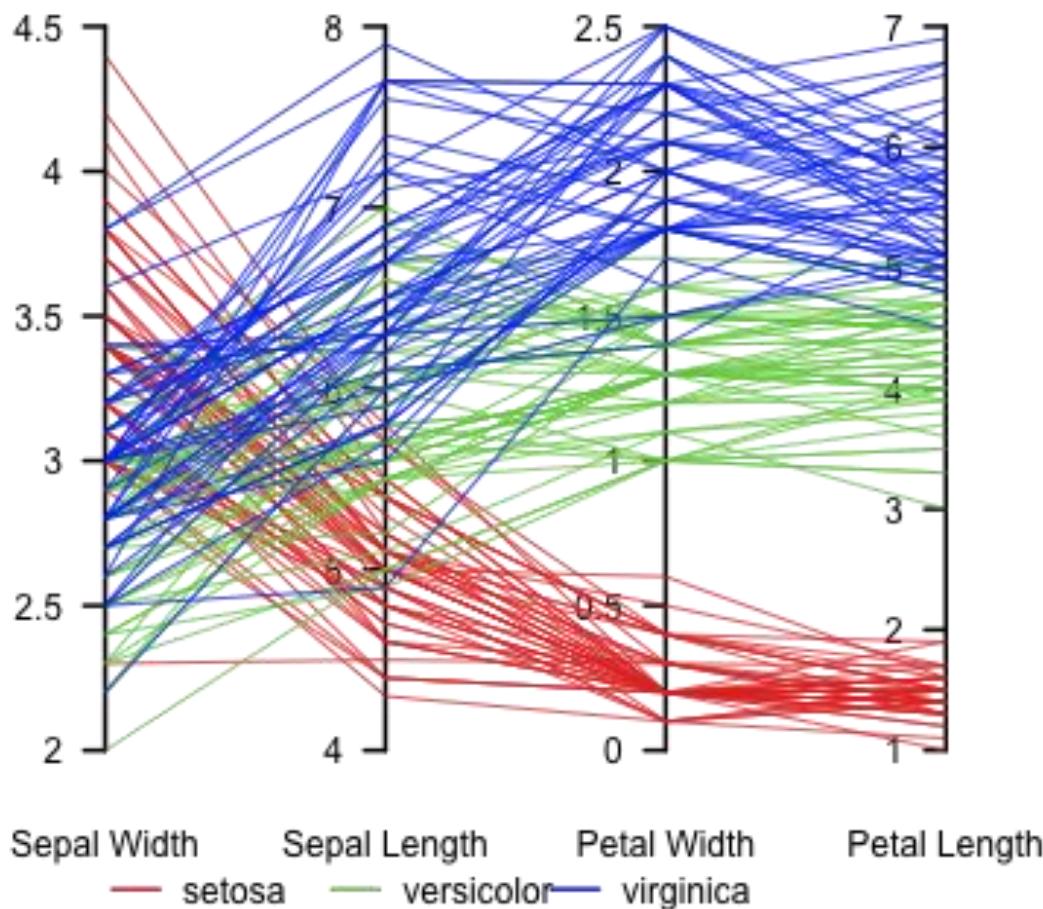


## Stacked bar chart

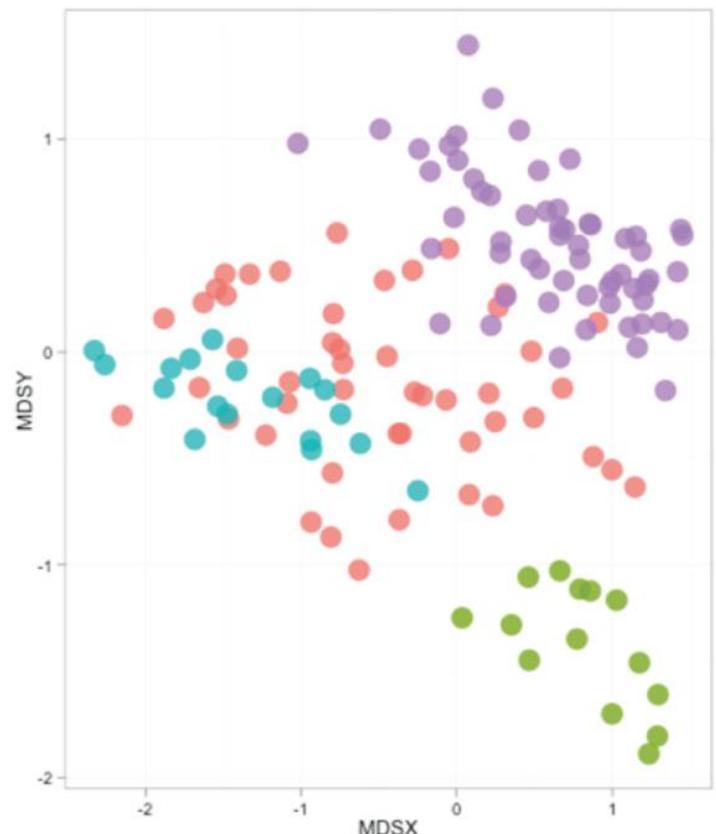
# Multi-dimensional/Multi-variate Data VIS

## Paraeel Coordinates [Inselburg]

Parallel coordinate plot, Fisher's Iris data

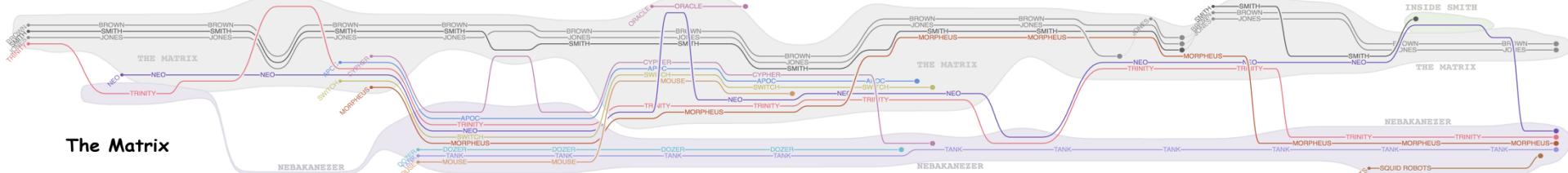
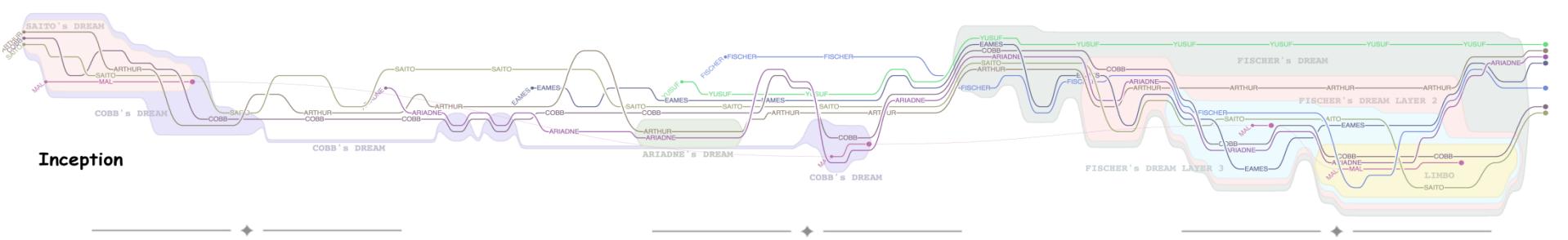
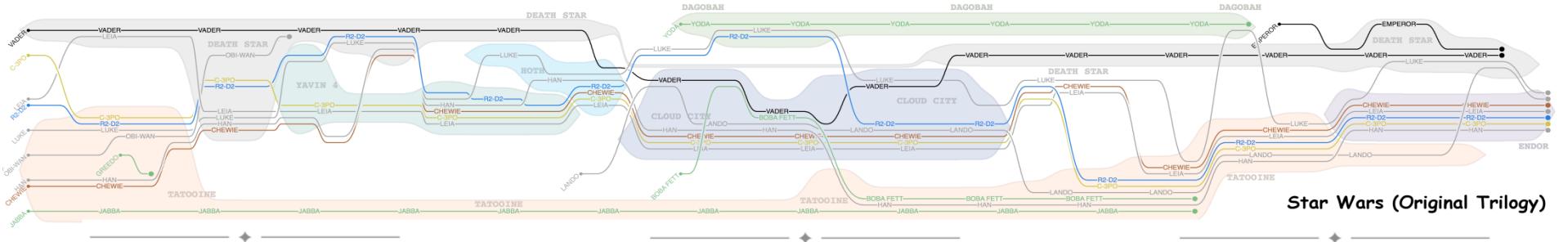
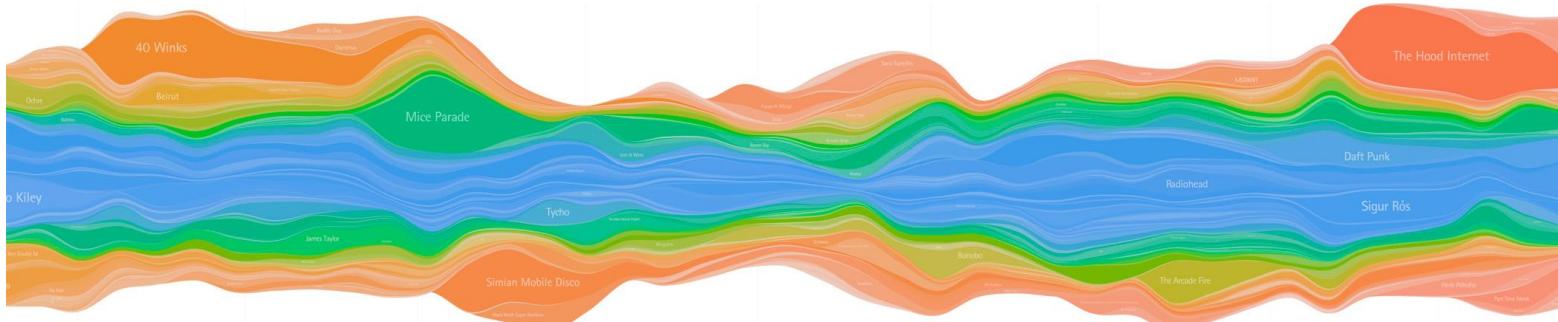


## Scatterplot using MDS (Multi-Dimensional Scaling)

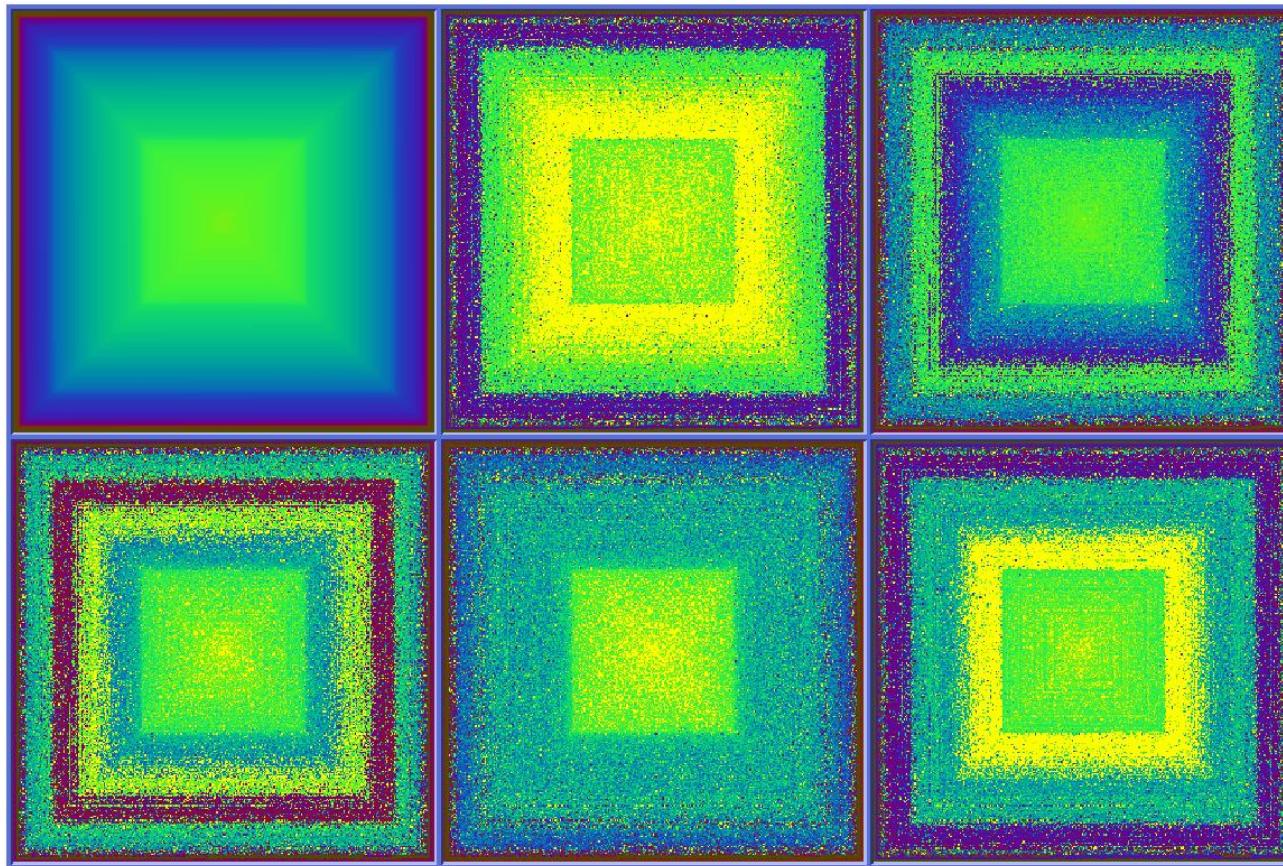


# Time-series Data VIS

## Stream graph Story-line



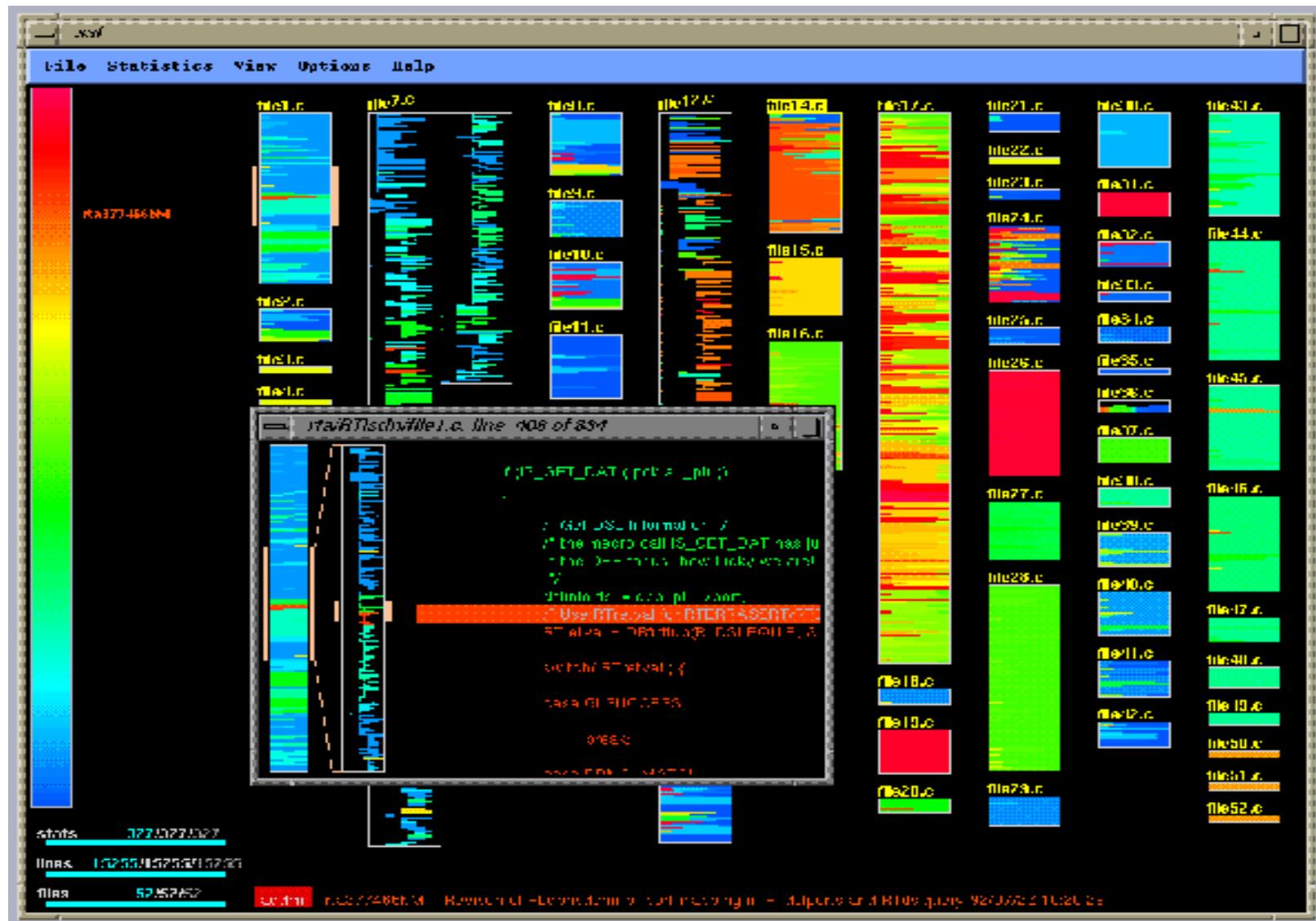
# Multi-Dim. Database Visualisation



**VISDB**

**Five-dimensional artificially generated data set (100,000 points) in simple configuration.**

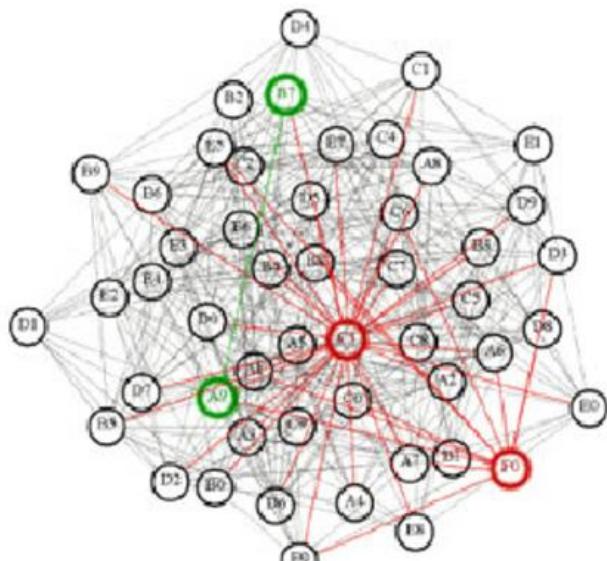
# Software Visualisation



# SeeSoft

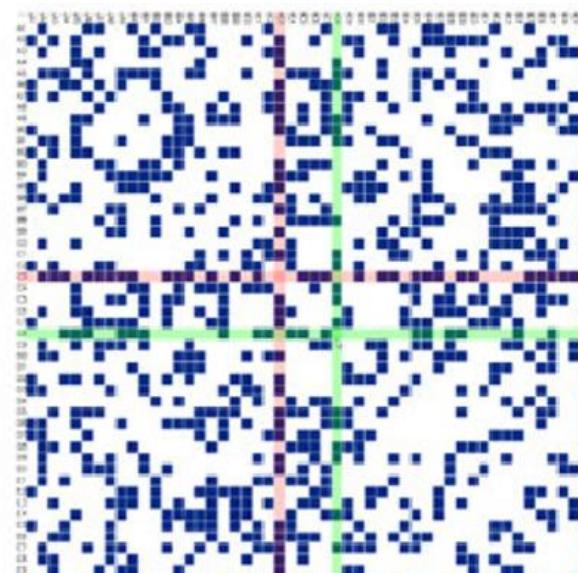
# Relational Data (Graph) Data VIS

Node-Link Diagram



a)

Adjacency Matrix



b)

# 4. Graph Drawing (Network Visualisation)

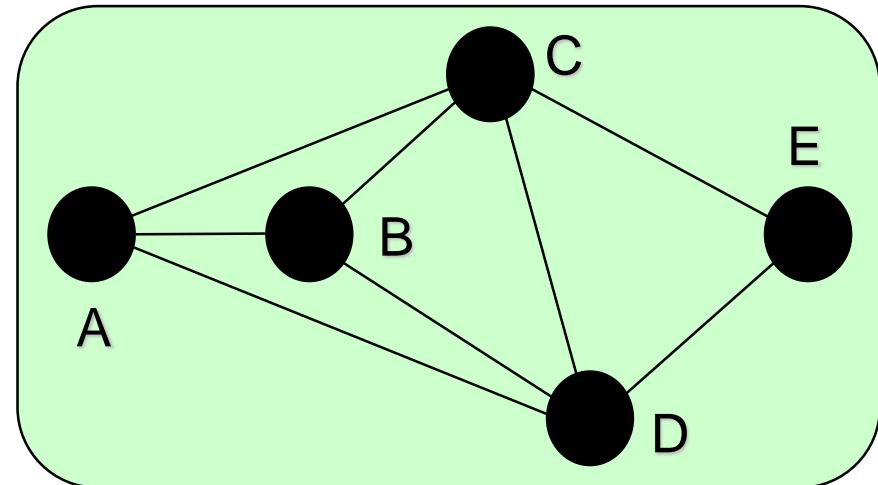
# Graph Drawing

- **Graphs:** abstract structure to model relational information.
- **Graph  $G=(V,E)$** 
  - $V$ : set of vertices (objects, entities)
  - $E$ : set of edges connecting vertices (relationship)
- **Graph Drawing:** automatic construction of good geometric representations of graphs in 2D or 3D.

The input is a graph with no geometry

*The output is a drawing of the graph; the drawing should be easy to understand, easy to remember, beautiful.*

A - B, C, D  
B - A, C, D  
C - A, B, D, E  
D - A, B, C, E  
E - C, D



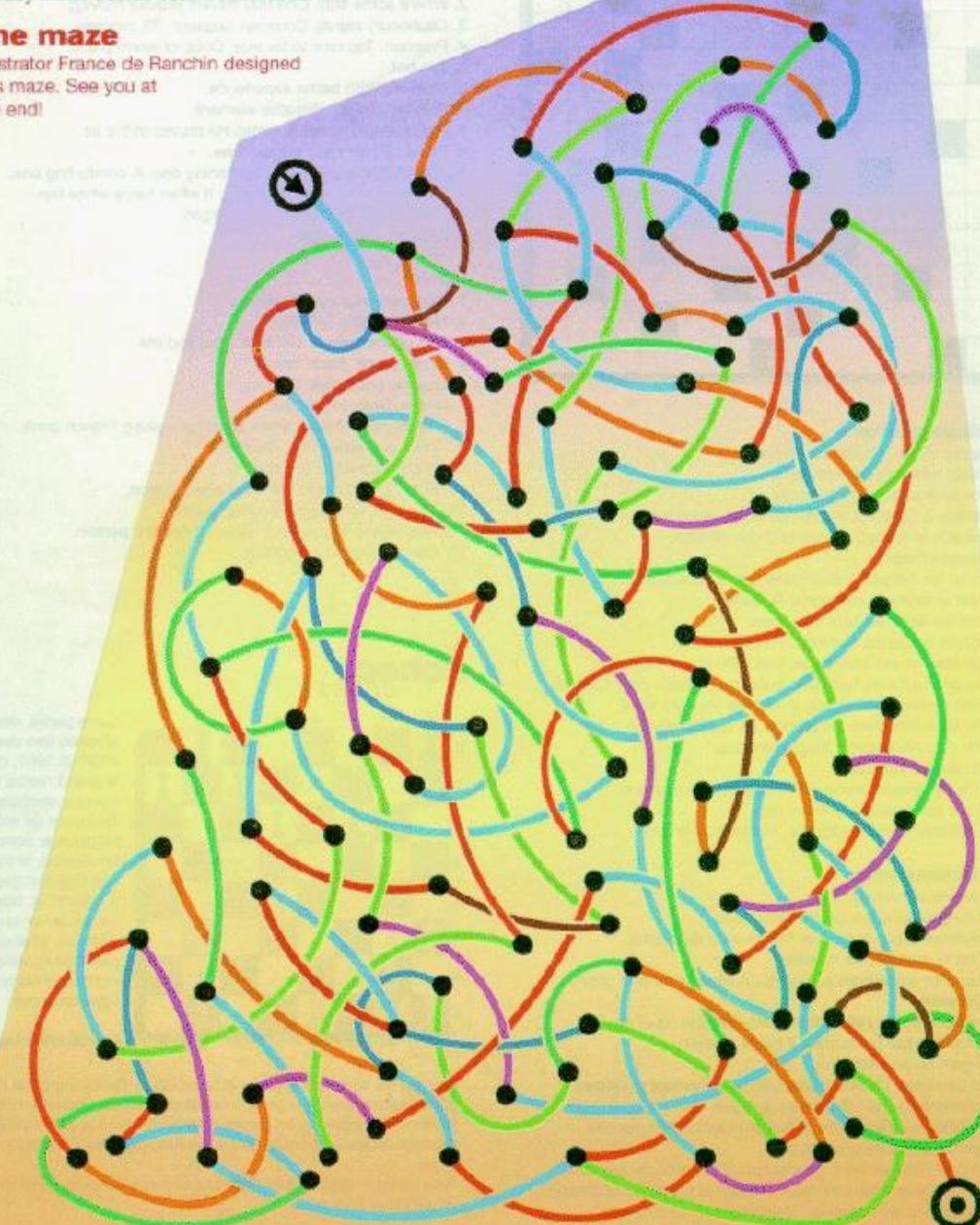
# Tangled Drawing

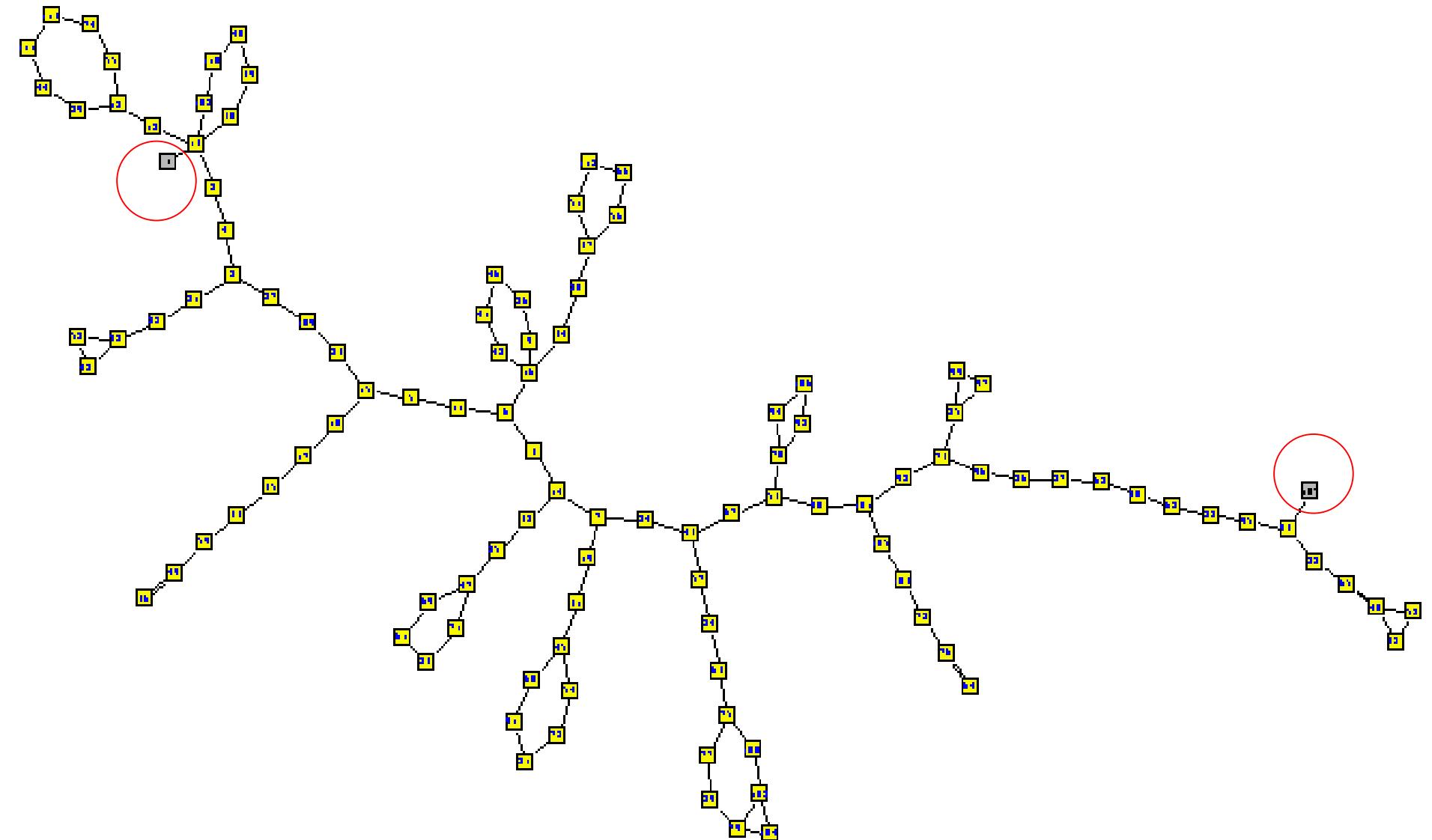
## Le labyrinthe

La dessinatrice France de Ranchin a imaginé ce labyrinthe. Saurez-vous trouver la sortie ?

## The maze

Illustrator France de Ranchin designed this maze. See you at the end!



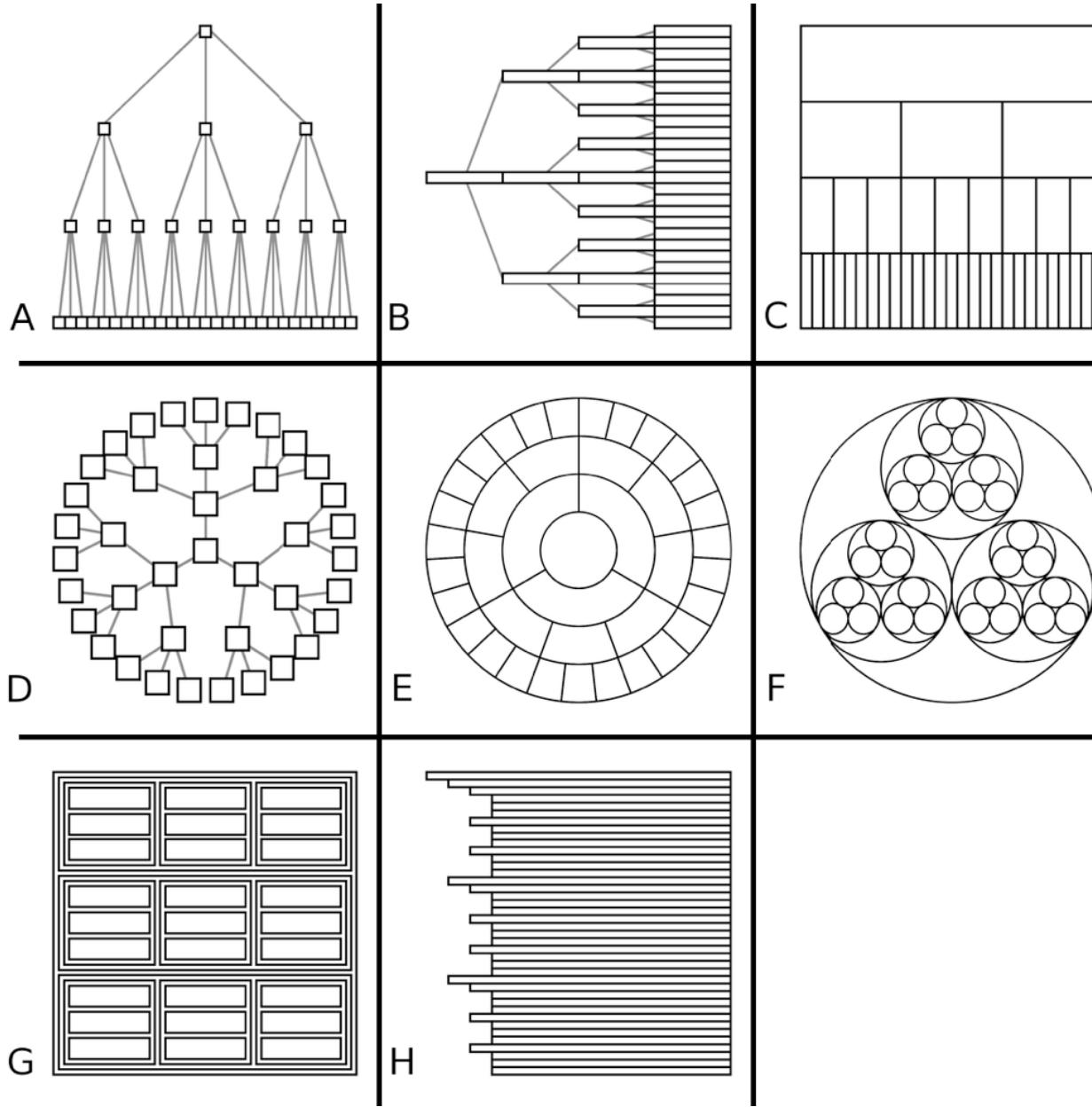


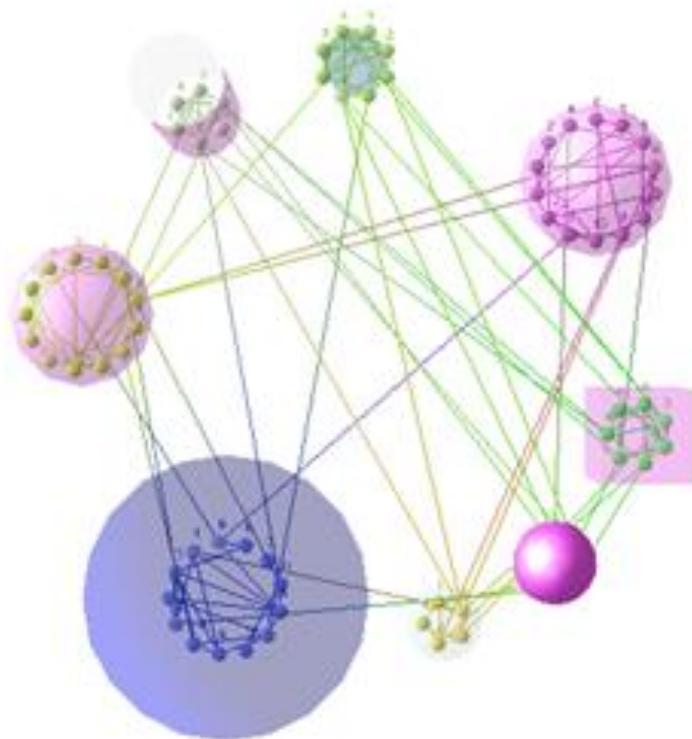
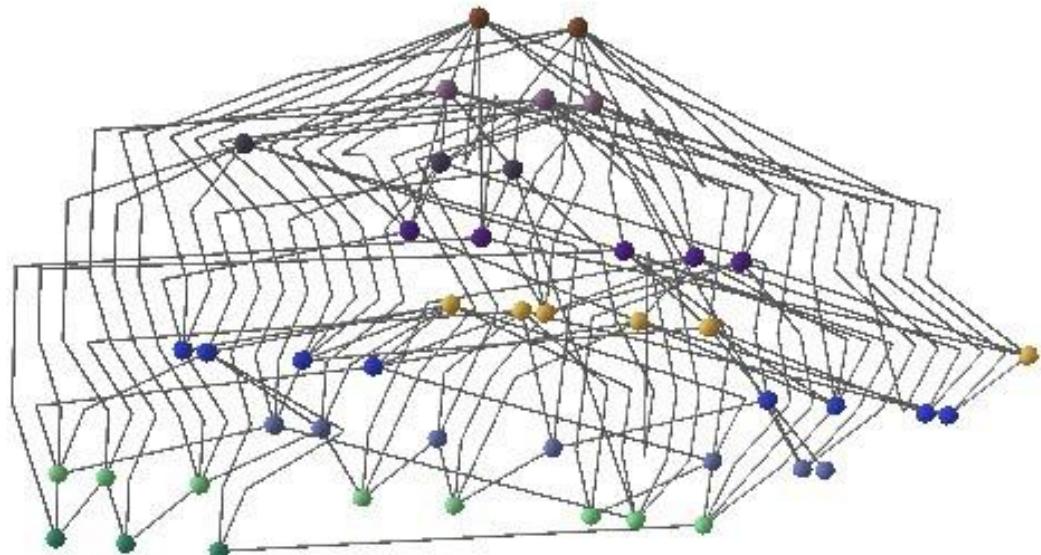
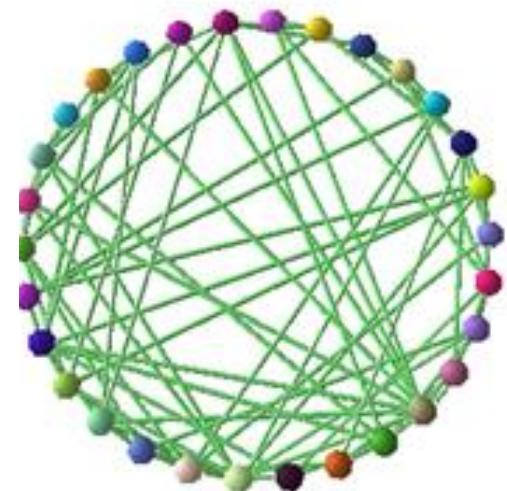
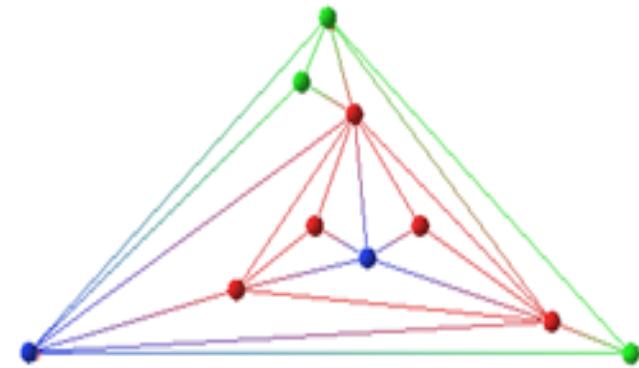
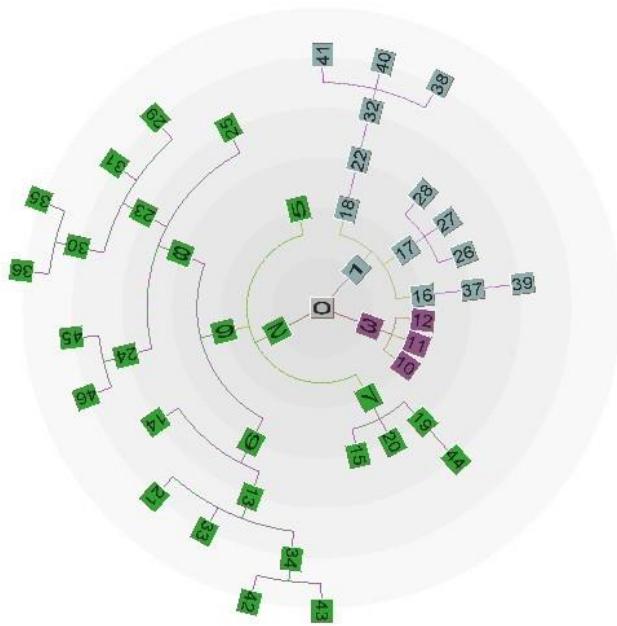
**Untangled Drawing**

# **Graph Classes**

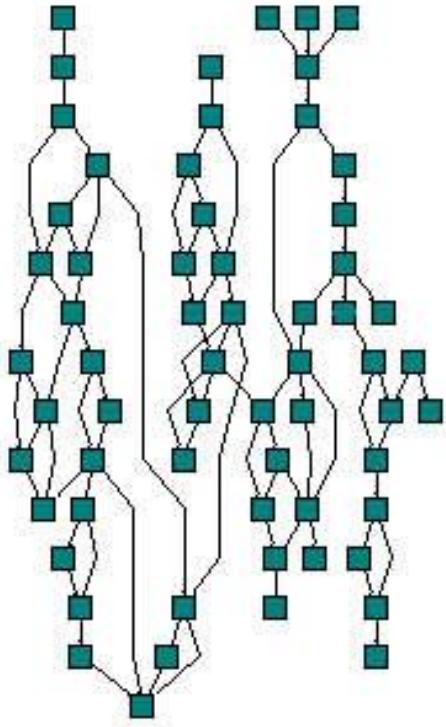
- **tree**
  - **free tree**
  - **binary tree**
  - **rooted tree**
  - **ordered tree**
- **planar graphs**
- **general graphs**
- **directed graphs**
- **extended graph model**
  - **hierarchical graphs**
  - **clustered graphs**
  - **hyper graphs**
  - **higraphs**

# Tree visualisation

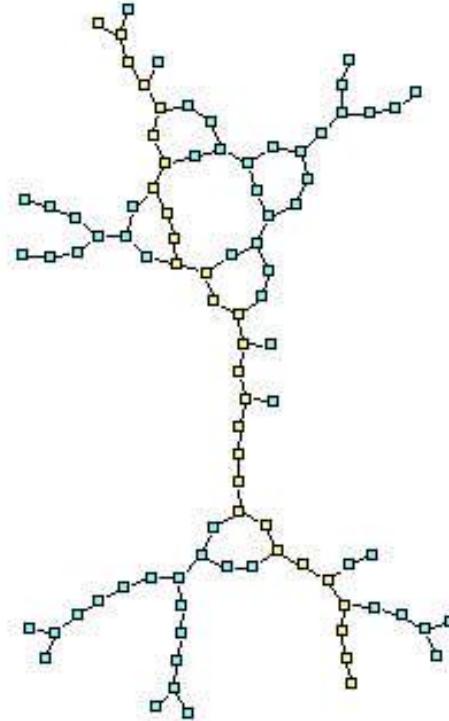




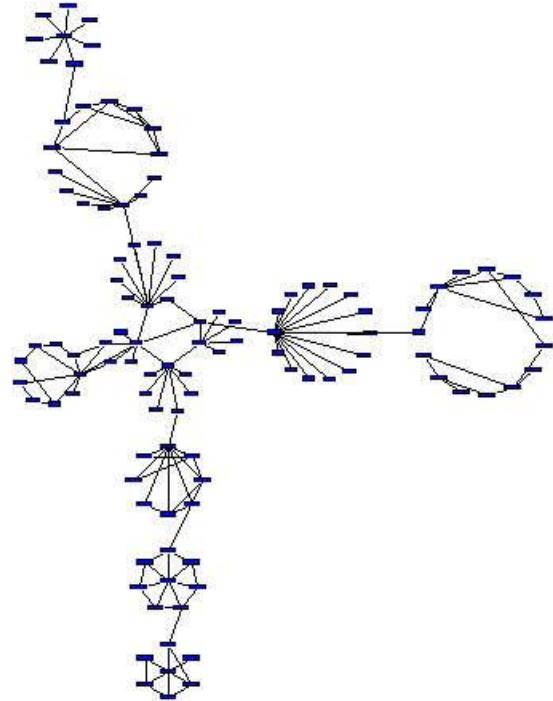
# Tom Sawyer Software, USA



Hierarchical layout



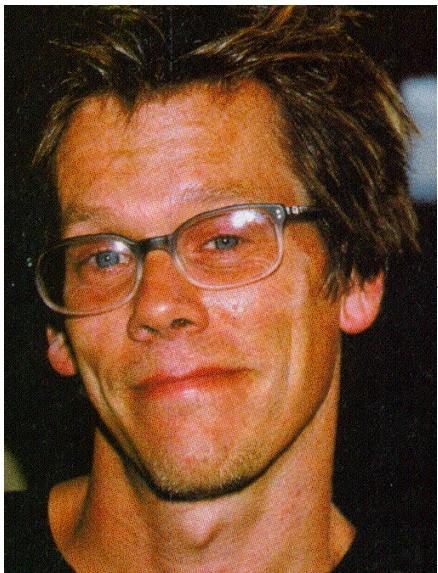
Symmetric layout



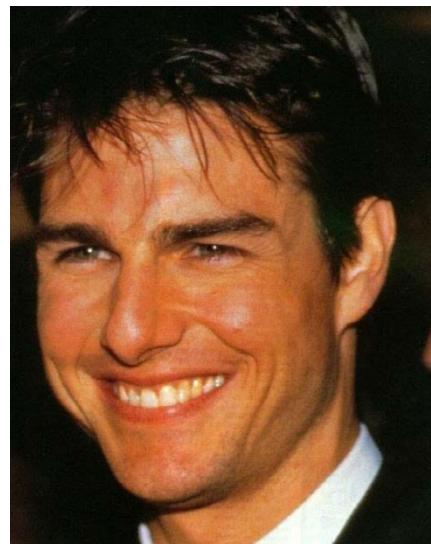
Circular layout



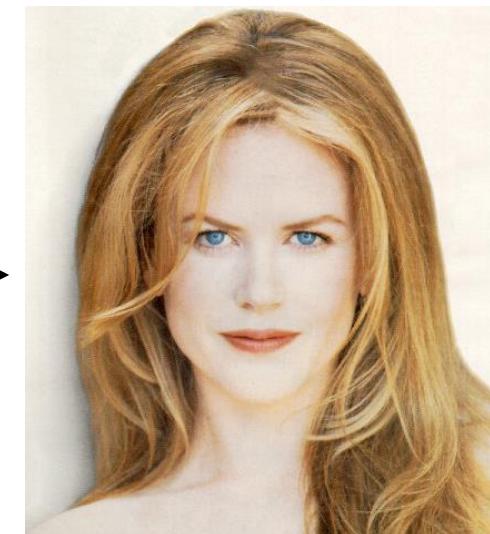
## Social Network: Movie Actor Collaboration Network



A Few Good Man

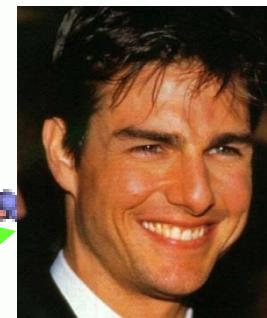
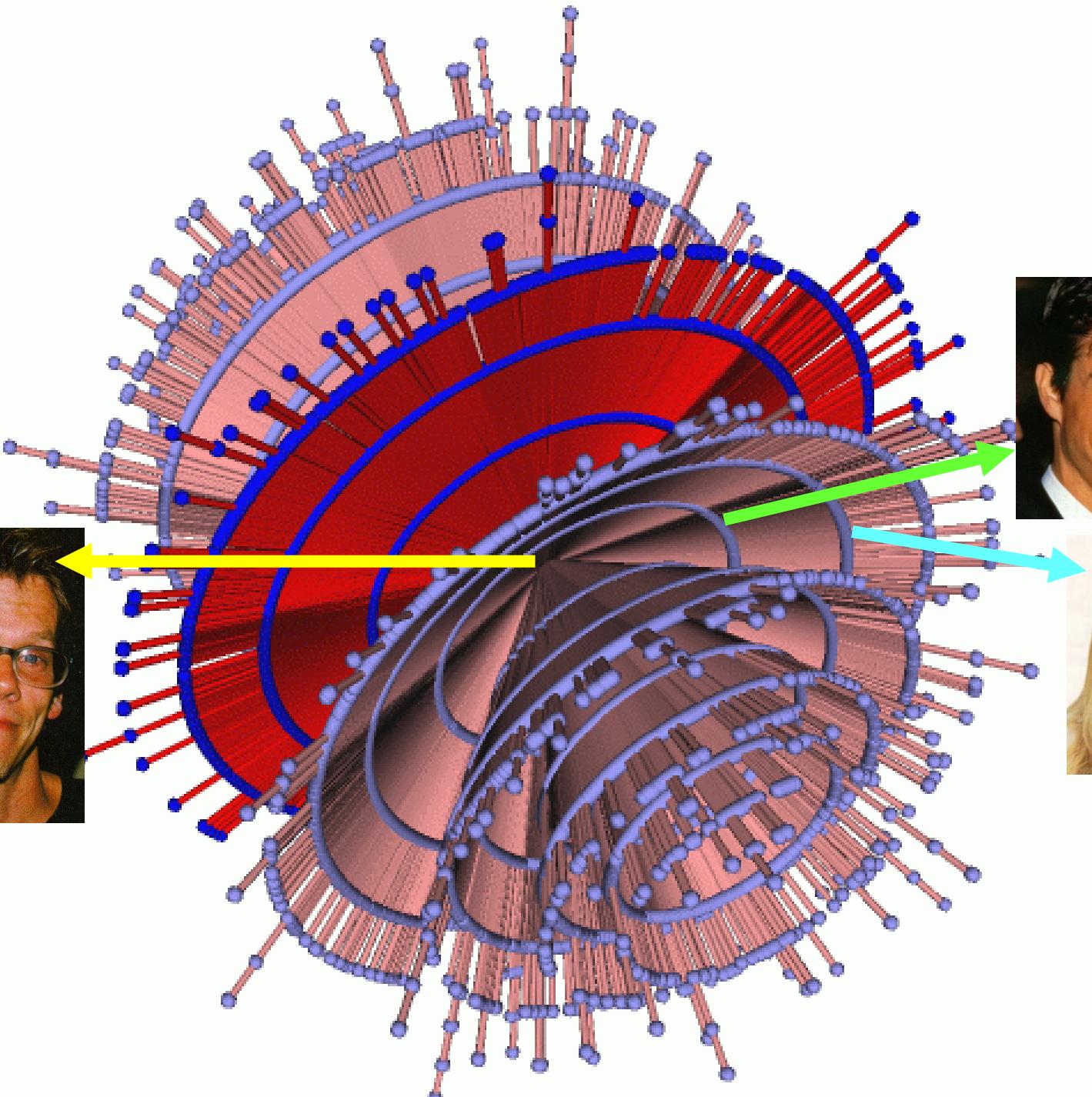
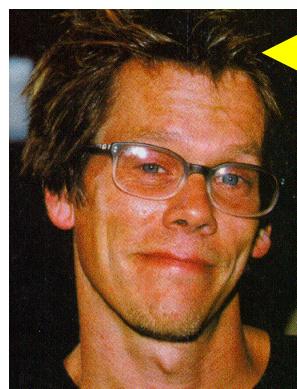


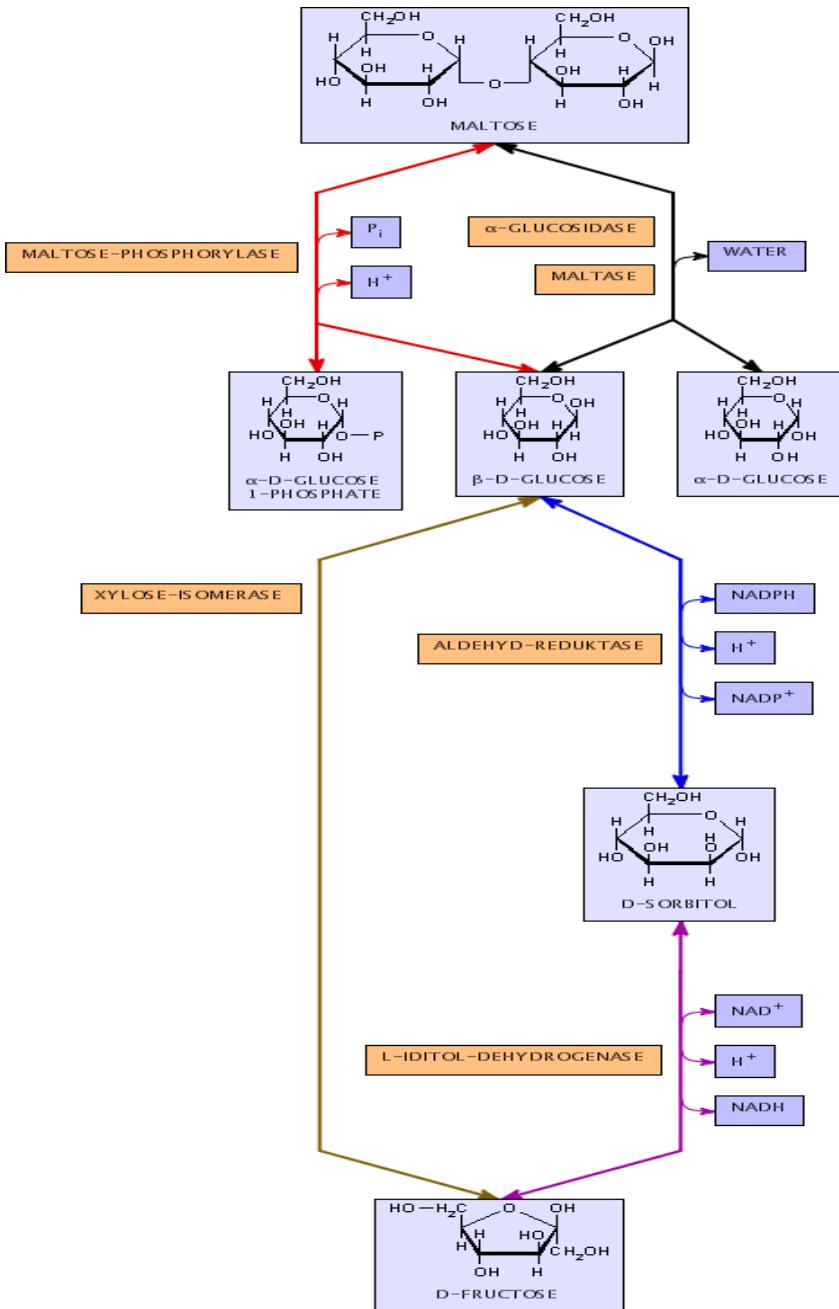
Days of Thunder (1990)  
Far and Away (1992)  
Eyes Wide Shut (1999)



Kevin Bacon Number 2

Kevin Bacon Number 1



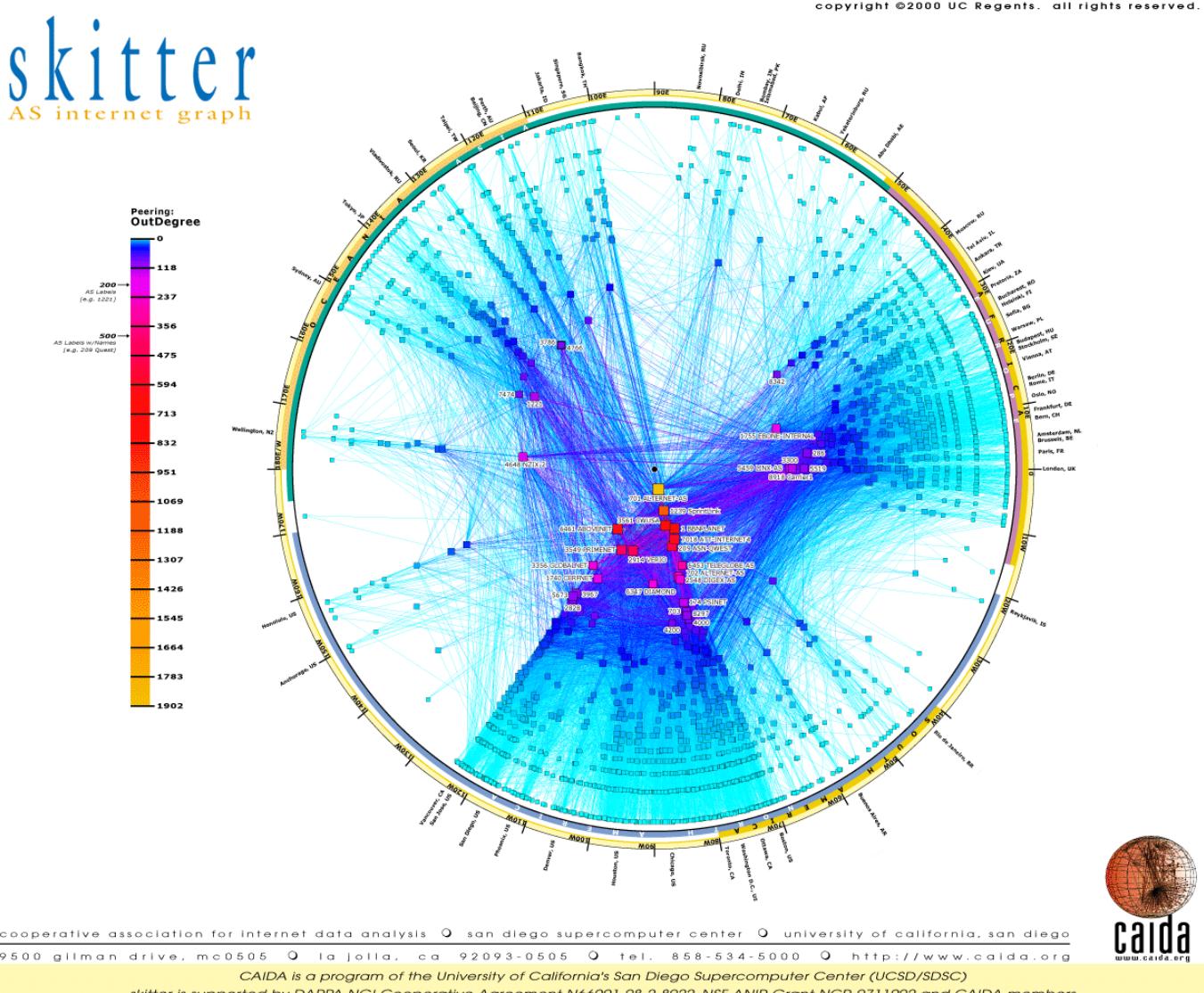


# Visualization of Biochemical Pathways

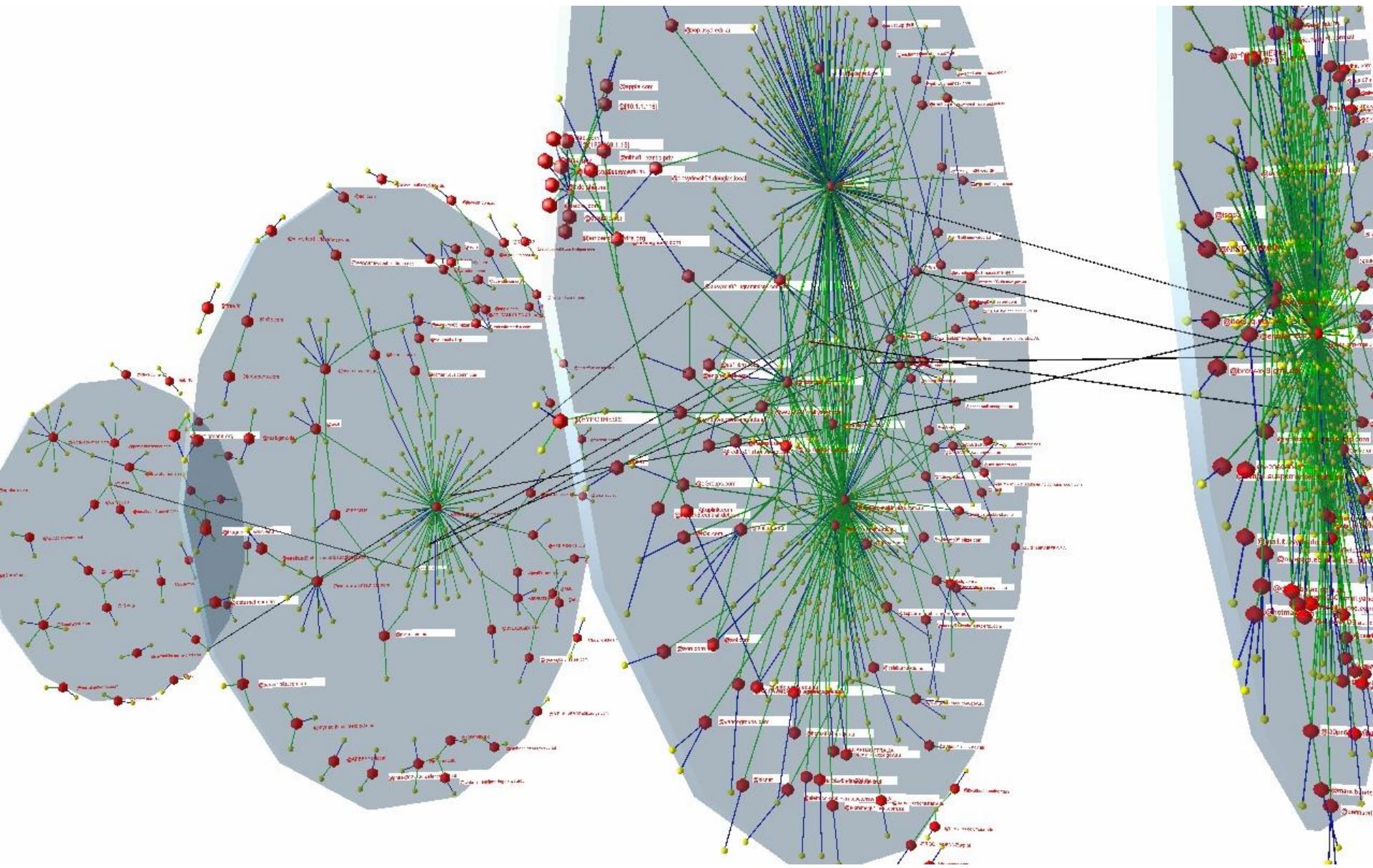
[Schreiber]

# The AS Internet graph

# A Macroscopic Visualisation of the Internet During October, 2000



# Cyber security: email-virus detection



## Homework: Tutorial Week 2

### (Install Tableau Now)

#### **Assumed Knowledge:**

- Big O notation:  $O(n)$  time etc
- Divide and Conquer Algorithm
- Trees: definition, terminology
- Tree Traversal: Inorder traversal etc

# Questions?