The Metro Map Problem

- Existing metro maps, produced by professional graphic artists, are excellent examples of network visualization.
- Can we produce good metro maps automatically?

A scientific challenge
Metro maps

Some notes:
- The topology of the geographical map is preserved, but not the metrics
- Stations are spread out in denser areas
- Railway lines are drawn as horizontal, vertical, and 45° lines
- Railway lines are as straight as possible

Scientific Question: Is there an E³ computer algorithm that can produce a layout of a metro map graph?

(E³ = Effective, Efficient, Elegant)

Scientific Question: Is there an E³ computer algorithm that can produce a layout of a metro map graph?

Effective metro map visualization
- Each metro route is drawn as straight as possible.
- Routes are mostly drawn horizontally or vertically, with some at 45 degrees.
- Avoid line crossings.

Efficient metro map visualization
- Drawing algorithms run fast

Elegant metro map visualization
- The method should be simple and easy to understand, easy to code, easy to maintain the code

The main problem is finding a good layout algorithm

Stations
- Attributes of each station
  - Location for box
  - Color, transparency
  - Shape of box
- ... 

Railway lines
- Attributes of each line
  - Route for line
  - Line thickness
  - Color
  - Linestyle
- ... 

Box for each station
- Line between boxes for each railway line
- ... 

Scientific Question: Is there an E³ computer algorithm that can produce a layout of a metro map graph?
One approach: use force directed methods

1. Define forces so that good layout corresponds to low energy
2. Use optimization methods to find a minimal energy state

The elegance of this force directed method means that it is
- Easy to code and maintain
- Cheap to code
- Fast time to market
- Easy to adjust and tune to new constraints

Are these force directed methods effective?

Some examples → → →
Virtual Environments

Case Study - Stock Market

MS-Guidelines

MS-Process

MS-Taxonomy

Software Engineering

Human Perception

Information Display

Data Mining

Abstract Data

many applications large

ABSTRACT

DATA

SOFTWARE

ENGINEERING

VIRTUAL

ENVIRONMENTS

HUMAN

PERCEPTION

DATA

MINING

MS-TAXONOMY

INFORMATION

DISPLAY

CASE

STUDY

MS-GUIDELINES

MS-PROCESS

finding

patterns

virtual

abstract

worlds

virtual

hybrid

worlds

data

characterisation

task

analysis

virtual real

worlds

new user-interface

technology

increase human-computer bandwidth

many interaction styles

perceptual

data mining

multi-attributed

visual

data

mining

information

visualisation

information

haptisation

information

sonification

VE platforms

guidelines

for perception

guidelines for MS-Taxonomy

guidelines for spatial
metaphors

guidelines for direct
metaphors

guidelines for temporal
metaphors

3D bar chart

moving average

surface

bidAsk landscape

haptic
3D bar chart

haptic moving average

surface

auditory bidAsk landscape

consider

software
platform

consider

hardware
platform

guidelines for information display

information perceptualisation

i-CONE process

structure

iterative prototyping

finding trading rules

stock market data display mapping prototyping evaluation expert heuristic evaluation summative evaluation formative evaluation

Haptic Workbench

Responsive Workbench

WEDGE Barco Baron

mapping temporal metaphors

mapping direct metaphors

mapping spatial metaphors

3D bar chart moving average surface bidAsk landscape haptic 3D bar chart haptic moving average surface auditory bidAsk landscape
The force directed method is a little bit effective, but not very effective.

It needs manual post-processing:
- This uses the time of a professional graphic artist
- Increases cost
- Increases time-to-market

Are the force directed methods efficient?
The force directed method is not computationally efficient. This means that:
- Expensive supercomputers (?)
- Larger problems cannot be solved at all
- Slow turn-around limits creativity

A big problem for network visualization methods that we know:
- They "do not scale"
  1. Pictures of large networks are not so beautiful
  2. Runtime is too large

Elegance: Yes!
Effectiveness: Maybe … OK but not great
Efficiency: No

The computational complexity problem

Force directed methods for metro maps "do not scale"
- Runtime is too large
- Some tangles in some larger maps

Effectiveness: the visual complexity problem

Big graphs

Social networks:
- Number of Facebook users

2004 2005 2006 2007
0 5M 10M 15M 20M 25M 30M 35M 40M 45M 50M

Auckland
London (20 sec)
Sydney (2 sec)
The scale problem(s)
As data sets grow in size, we have two problems:

1. **Visual complexity**: the pictures are a tangled mess
2. **Computational complexity**: the pictures take too long to compute.

1. **Visual complexity**
   - Too many edge crossings
   - Edge crossings at narrow angles
   - Resolution is poor
   - Geometric distance not related to network distance
   - Gestalt grouping not meaningful in the domain
   - ...

1. **Computational complexity**
   - The optimization problems associated with the measures of visual complexity are NP-hard