A Real Application of Visual Analytics for Healthcare Associated Infections

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A Case Study

- A spectrum of visual analytic techniques
- Illustrate a real-world application
Healthcare Associated Infections (HAI)

**Definition:**
HAIs are infections that patients acquire while receiving surgery and/or treatment for medical conditions in a healthcare setting such as hospitals (in- or out-patient) or nursing homes etc.

*Example infections:* Staphylococcus aureus, MRSA, Clostridium difficile, Norovirus, *etc.*

**Problems:**
In hospitals HAIs result in extended hospital stays, contribute to increased medical costs and are a major cause of morbidity and mortality.
They also lead to logistic and economic problems for healthcare services.
World Health Organisation (WHO)

HAIs will continue to rise:

- Crowded hospital conditions
- Increasing number of people with compromised immune systems
- New micro-organisms
- Increased bacterial resistance
Infection Causes

The infections may be caused by:

• bacteria
• fungi
• viruses
• parasites
• prions
Routes of Transmission

- Contact:
  - Direct (person to person)
  - Indirect (contact with contaminated surfaces touched by infected person or spread on unwashed hands, etc.)
- Airborne:
  - droplets from an infected person released when coughing or sneezing
- Water borne:
  - contaminated water
- Blood exposures
Hospital Infection Surveillance

It is now increasingly recognised that rates of infection can be lowered significantly by a combination of:

– good hygiene practice
– careful use of antibiotics
– improved techniques and devices

Surveillance is the key factor
Objectives

Monitor infections and detect outbreak by:

• Analysing and understanding the infection
• Visually analyse which ward specialities, wards or hospital buildings pose more infection risks
• Visually analyse which ward specialities, wards or hospital buildings have an effective infection control strategy or record
• Monitor patients’ status and movements and detect:
  • Anomalies
  • Clusters
  • Patterns
  • Relationships
  • Trends

Detect and identify potential outbreaks in a more timely manner
Dataset

Dataset of patient information of an example infection:

- 4 year period
- 447 patients
- 8479 admissions
- 10 hospital buildings
- 127 wards
- 14 medical specialities

This is real data
Data

Excel spreadsheet data:
- Patient ID
- Admission date
- Discharge date
- Hospital building
- Ward
- Ward speciality
- First time tested positive for infection
- Last time tested positive for infection

Real data like this is never perfect for the analysis task at hand
Data Analysis and Exploration
Why ‘Visual’ Analytics

- The spreadsheet contains over 8000 records
- Unless this is analyzed visually it is impossible to understand and assimilate
- It will be seen that even analysing the data visually is challenging
- Without interactive visualisation it is impossible
A Range of Example Visualisations
Patients and their associated admissions. Each horizontal line represents a patient and the colour corresponds to the hospital building into which s/he was admitted. The number of admissions for each patient varies widely. Some patients were only admitted once while some were admitted more frequently, e.g. 755 times.
Patient P8878656

755 points in P8878656

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Number of Patients Admitted In Each Hospital Building

CH admitted the greatest number of patients over the 4 year period while CI had the fewest patients admitted.
Patients Tested Positive While In Hospital

450 in-ward infections out of 8479 admissions colour corresponds to hospital building
In-ward Infections

![Bar chart showing infection rates by location]
Number of Infections in Each Hospital Building

The highest increase in positive tests was registered in hospital building JR. This could be due to a relatively higher numbers of patients going through this hospital building or the particular conditions treated at this building.
Seasonal Variation Across All Hospital Buildings

Shows the aggregated monthly analysis across all the hospital buildings over the four year period. It is hard to attribute any particular pattern: February, July, August and September had the lowest incidence. November had the highest incidence, twice that of September.
Positive Tests in Each Hospital Building

- Positive Cases for Hospital CH
- Positive Cases for Hospital HG
- Positive Cases for Hospital JR
- Positive Cases for Hospital CI
- Positive Cases for Hospital RI
- Positive Cases for Hospital WW
- Positive Cases for Hospital WC
The total number of tests performed at JR building greatly out-numbers the number of tests performed in the other hospital buildings.
Infection Frequency Plots

Histogram of infections per day
Patients’ Hospital Stay Scatter Plot

Number of days a patient stays in a ward, each dot represents a patient (x-axis) and the number of days s/he stayed (y-axis) and the colour represents the hospital building in question. Stays vary from day-visits to 147 days.
The number of days that the patients stayed in the ward before tested positive varies from 0 to 77 days.
Parallel Co-ordinate View

Parallel co-ordinate view provides an effective visualisation of a high dimensional multi-variate data such as this. Highlight in yellow are all the patients associate with a particular hospital building.
Linked View Visual Analytic

Linked view greatly eases information assimilation
Geo-temporal Visual Analytics
A geo-temporal visualisation and analytics of patients and their contacts moving in and out of hospital and around within hospitals

A system to enable infection control personnel to:

• Visually analyse patients’ movements, status and interactions
• Filter data
• Query individual patients
Visual Interface of the Hospital Buildings and Community

Each ward is colour coded by its speciality
User Control Panel
Patient Representation

Each patient is represented uniquely by:
• An icon with a letter and a background colour.
• The letter is:
  • **White** when the patient is not infected,
  • **Red** when the patient is infected and
  • **Pink** when the patient is notionally recovering
  • **Grey** when the patient has recovered

The letter will flash **red** when the patient is tested positive to draw attention to his/her new status.
Visualisation and Analysis of Patients’ Movements

Streak lines represent patient movement, from the darker end to the lighter end. In this frame a patient F can be seen being admitted to a ward within ward speciality 2 in hospital building JR from outside the hospital system.
Patient’s Details
Surveillance - Patients’ Status

Seven patients and their status (non-infected) on the 20th April, there is no discharged patient
Patients on 4th November

There are 2 infected and 26 non-infected patients across the hospitals and 125 non-infected and 3 infected patients in the community.
Patients on 28th November
Patient Filtering
Contact Tracing – Patient (554314)

Patient 554314 had 14 contacts
Demonstration
Conclusions

Visual analytics provides the only practical means of exploring, analysing and understanding large and complex raw datasets of patient information

The geo-temporal visualisation tool can be used with minimal training
Conclusions

• It is impossible to understand and analyse the data in its raw spreadsheet form
• Visualisation is essential for analysing inherently ‘non-visual’ spreadsheet data
• Beyond graphs more sophisticated techniques such as geo-temporal visualisation are essential, but they become more specialised and more difficult to implement
• Visual Analytics provides an effective and intuitive means for exploring data to detect trends, clusters, recurring events, etc.