e-Science in the Streets: Urban Pollution Monitoring

Anthony Steed, Salvatore Spinello,
Department of Computer Science, University College London
***Ben Croxford**, Bartlett School of Architecture, University College London*
***Chris Greenhalgh**, School of Computer Science & IT, University of Nottingham*

Outline

- Air Pollution
- System Overview
- Data Modelling
- Results to Date and Current Activities
- Conclusions

1. Air Pollution

- Carbon Monoxide (CO):
  - Is caused by transport
  - Hence affects urban areas more than rural areas
  - Suggested standard of 10ppm (11.6mg/m3) [5]
  - Localised peak of 12ppm in the vicinity of UCL (Croxford et al.)

Air Pollution Monitoring

- A nationwide network of 1500 sites
  - Online archives going back over 30 years in some instances
- However:
  - CO disperses relatively rapidly over time and space
  - Croxford study found significant variations in a sensor network covering a small area

Mobile Monitoring…

- …to bridge the gap between wide-area, sparse surveys and small-area, dense surveys
  - Comprises GPS receiver and CO sensor from Learian Designs
  - Based around a HP Jornada 568 Handheld PC

Early Prototype

Mobile Data

- Current five mobile devices, each carried by a user or placed on a bike rack:
  - Multiple paths of GPS and pollution level
  - Data from fixed sensors to support calibration
- Paths can be ‘woven’ together to form a map of pollution
  - Gives a picture of how pollution varies spatially and temporally across the local area

2. System Overview

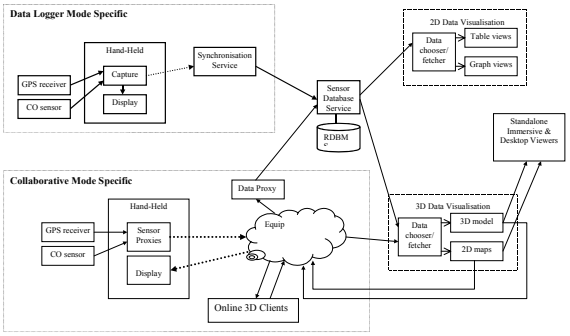
- Two operating modes are being developed:
  - **Data Logger Mode**
    Device collects data and uploads it when synchronised to a desktop
  - **Collaboration Mode**
    Device has network access with collaborators and shares data in real-time

EQUATOR

Data Logger

- Prototype device:
  - runs Windows CE
  - stores data on local flash disk
  - has a live display showing pollution level and a diagnostic about GPS coverage and location
- Synchronising the device to a laptop uploads data to a database

EQUATOR

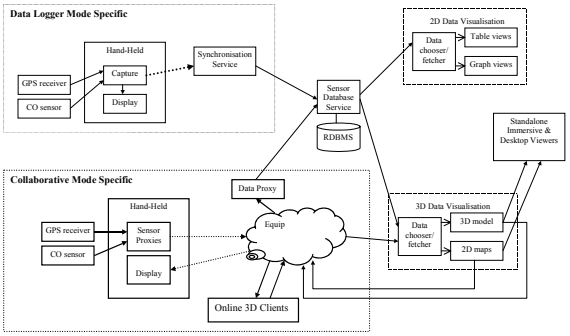


EQUATOR

Collaboration Mode

- Device supports:
  - Intermittent wireless connection
  - Real-time communication with other clients through the EQUIP system
  - Extending infrastructure of EQUATOR City project
  - (First prototype device cannot support wireless connection at the same time as GPS and CO logger – fixed with 2nd generation prototype)

EQUATOR



EQUATOR

3. Data Modelling

- Visualisations are based in 3D models
  - CO is affected by local building configuration
- Pollution paths from the mobile devices are interpolated to create a pollution field
- Pollution field and 3D model are integrated so that users can readily see variations based on local topology

EQUATOR

Modelling 3D Cities

Step 1: Create a Delaunay triangulation of vector maps and classify all areas

Step 2: Use height data to create the ground surface and specify building heights

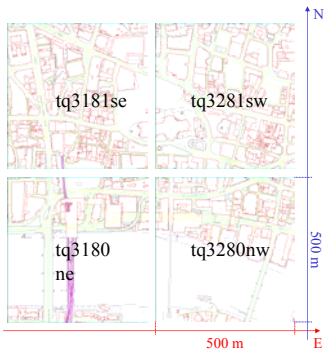
Step 3: Extrude polygons and fit facades

Step 4: Drape aerial photography

Step 5: (Optional) Insert street furniture, procedurally texture facades and optimise model

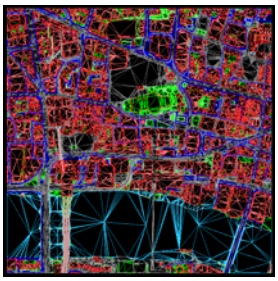
EQUATOR

Step 1: Land-Line data of an area around St. Paul' Cathedral



EQUATOR

Step 1: Constrained Delaunay Triangulation

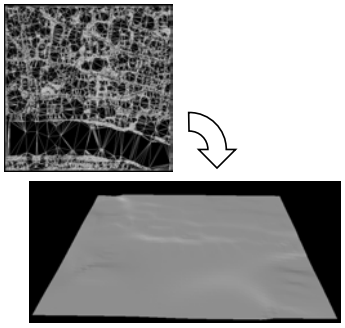


Buildings, Streets, Pavements, Water and others real features are identified and classified.

EQUATOR

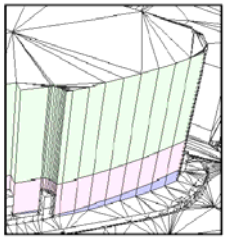
Step 2: Height data

- *LIDAR (LIght Detection And Ranging) – a form of aerial surveying*
- *Roughly 30 spot heights in 100 sq m*
- *Data is interpolated using same scheme as for pollution data in order to generate a smooth surface*



EQUATOR

Step 3: Building Extrusion



- *Take into account non-planar surface and any need for multiple layers of texture mapping on the facades*
- *Roofs are flat. Better LIDAR data would allow us to robustly determine roof shape*

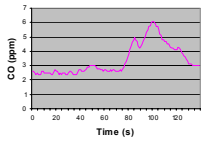
EQUATOR

Step 4: Drape Aerial Photography

EQUATOR

Data Modelling

- Individual paths are not easy to analyse since they have spatial properties
- However simple 2D clients are available for the database



Raw data from a segment of a path near UCL

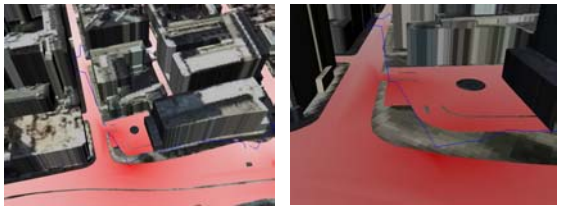
Data Modelling

- An inverse distance weighting scheme is used to create a smooth pollution surface
- Shepard's Method to calculate pollution at *x, y*

$$F(x,y) = \sum_{i=1}^{n} w_i f_i \qquad w_i = \frac{h_i^{-p}}{\sum_{j=1}^{n} h_j^{-p}}$$

- Where f_i are the original pollution values, h_i is the distance to the location of this pollution value, and p is a positive number, usually p=2

4. Results



View of the junction of Gower St and Euston Road

Current Activities

- Two second generation prototype devices:
  - One as a dedicated data logger, based around a PIC chip.
  - One using the Bitsy wearable device as used in the EQUATOR/MIAS Medical Devices e-science project

Role of GRID Infrastructure

- Planning to integrate back-end software with example GT3/GRID infrastructure as prototyped by associated EQUATOR e-Science projects
- GRID infrastructure is only applicable to back-end services since individual mobile loggers can't now, and probably shouldn't be GRID services
- Relationship between GRID services and real-time collaboration system over EQUIP is uncertain.

5. Conclusions

- Have demonstrated a novel approach to pollution monitoring using mobile sensors
- Wide-scale and densely sampled maps of pollution will enable novel types of monitoring and science to investigate, e.g. impact of traffic congestion or the impact of pollution on users
- Potential to become a public understanding of science activity where members of public contribute their own data to a public data repository