Open Access to Hydrological Models through Interactive Spatio-temporal Animations

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Topics in this presentation

- Health-e-Waterways project
- Hydrological transport models
- The Receiving Water Quality Model
- Barriers to sharing and re-use of model results
- Objectives for open and interactive access
- Software architecture
- Software demonstration
- Evaluation and conclusion

Project website
http://www.health-e-waterways.org/
Health-e-Waterways project

http://www.health-e-waterways.org/

Integrated water information management for South-East Queensland

Collaboration between:
• The University of Queensland
• Microsoft Research
• Healthy Waterways
  – Queensland government (DERM), local governments,
  – federal government (CSIRO, DEWHA),
  – state corporations (Seqwater, WaterSecure),
  – universities, research organisations, industry, community groups.

3 years funding (Microsoft Research, ARC Linkage, SmartState NIRAP)
Health-e-Waterways project

http://www.health-e-waterways.org/

What will be the ecosystem health outcomes of the implementation of landscape restoration works in the Logan Albert System by 2026?
Hydrological transport models

Case Study: The Receiving Water Quality Model

Hydrological transport models provide mathematical formulations of water ecosystems, designed to simulate hydrodynamic and water quality variations in a water body subject to external factors.

Vital tool in understanding and improving health of water ecosystems

The Receiving Water Quality Model (RWQM)

• In 2005, Healthy Waterways contracted BMT WBM to apply the RWQM to identify optimum water resource management strategies for the Moreton Bay system in South-East Queensland.

• Scenarios for total loads of nutrients and sediments based on:
  – projected population increase,
  – impacts of upgrading or removing wastewater treatment plants,
  – diffuse load reductions, and
  – deployment of stormwater quality improvement devices.
Receiving Water Quality Model
Hydrodynamic and water quality model for South-East Queensland

Model inputs
- hydrodynamic (freshwater flows, tidal forcing, velocities)
- meteorological (wind speed and direction)
- water quality (loads from point sources, catchment loads)

Model outputs
- hydrodynamic (water surface elevation and velocity)
- water quality (spatial concentration of nutrients, chlorophyll a, sediment, biochemical oxygen demand, other physical indicators)
Receiving Water Quality Model
Finite element-based model for the Moreton Bay system

Geometry → Hydrodynamics Model → Hydrodynamics results → Water Quality Model → Water Quality results
Limitations of current modelling practices

Issues preventing sharing and re-use of model results

Barriers preventing sharing and re-use of model software
• Need to purchase and install proprietary desktop application
• Require access to input data, boundary conditions, etc.
• Time and computational demands of model execution

Barriers preventing sharing and re-use of model data
• Volume of input and output data required by models
• Model scenarios and results stored in proprietary formats

Results presented as static tables, graphs, or bar charts
• Limited to set of fixed regions, indicators, and time periods
• Doesn’t enable interactive exploration of models
• Doesn’t support access to or re-use of underlying data
Other efforts to provide access to models

Existing work related to this project

Online model directories
- Provide information to potential users of models
- But need to download, install, and configure modelling software

Online model viewers
- Best example is USGS SPARROW Decision Support System
- Does not support scenario selection, animation of model outputs
- Based on Oracle products (MapViewer, spatial and database)

See conference abstract for further details and references.

None of the existing approaches
- provide simple access to users with no modelling experience,
- support interactive browsing and animation of scenario results,
- and use open geospatial standards to maximise data re-use.
Open Access to Hydrological Models through Interactive Spatio-temporal Animations

Our objective is to support the storage and indexing of modelling data using open standards, so that users with little or no modelling experience can quickly and easily select scenarios and visualise model results as interactive animations through a Web browser.

Benefits of our approach

• **Runs in a standard Web browser**, avoiding need to install proprietary applications.

• **Models pre-executed and cached**, avoiding model processing time/complexity and large data volumes.

• **Adopts open standards and open-source geospatial platform**, making previously inaccessible datasets available to a wide audience.

• **Provides interactive access to geospatial visualisations**, allowing users to better understand impact of alternative scenarios.
Software architecture
Health-e-Waterways model repository

Data model
• Describes models and model scenarios
• Represents model results for each scenario

Conversion software
• Converts proprietary model outputs into standard data model
• Stores in database with spatial/temporal indices

Server components
• Makes geospatial data available via Web-based protocols
• Generates cached results, produces indicator charts

Web browser-based graphical user interface
• Allows users to interactively select scenarios
• Renders results as streamed geospatial animations
Data model for models, scenarios, and results

UML class diagram including example values
Data processing components
Extracting geometry, hydrodynamics, and water quality results

Geo to PostGIS Converter
Reads binary-format geometry file and converts to *grid element* entities stored in PostGIS.

Model to PostGIS Converter
Takes input for scenario title and scenario parameter values.
Reads binary-format result files for hydrodynamics and water quality models, storing time-series snapshots that capture the water velocity and fourteen water quality indicators at each grid element.
Geo to PostGIS Converter

Extracts geometry from Moreton Bay finite element model

Maps each finite element node (approx. 7800-18400), using nearest-neighbour algorithm, to a corresponding *grid element*, stored in PostGIS.

Results in 33491 grid elements at size 0.0025×0.0025 degrees.
Model to PostGIS Converter
Extracts data from hydrodynamics and water quality result files

Reads hydrodynamic and water quality results for each of the time-series snapshots that comprise a modelled scenario.

- Extracts values for water velocity and fourteen water quality indicators (e.g. Dissolved Oxygen) for each finite element node.
- Maps from finite element nodes to grid elements, storing values for each grid element per snapshot in a PostGIS database.
Data storage, serving, and visualisation
Server- and client-side components for publishing models

Client side
Dynamic HTML and JavaScript based on the OpenLayers library.
Google Earth for KML rendering.

Server side
Health-e-Waterways Java application server.
GeoServer, connected to PostGIS-enabled PostgreSQL database.
GeoWebCache, integrated with GeoServer to manage cached tiles.
GeoWebCache
Caches map tiles based on stored model results

We specify a ‘grid set’ corresponding to the Moreton Bay region, defined in terms of its bounding box and several predefined zoom resolutions.

Cached map layers are defined by style and parameter values:
• fourteen possible styles corresponding water quality indicators;
• for each style, need images for each scenario;
• for each scenario, need images for each time-series snapshot;
• for each snapshot, need images for predetermined zoom levels.

Caching RWQM scenario results for 174 snapshots:
• Requires 205,800 PNG images, consuming 1.1 GB of disk space.
• The number of tiles for higher zoom levels increases exponentially.
• Individual tile images are small (an average of 5 KB) and are therefore transmitted and loaded very quickly by the Web browser for display in map animations.
Model scenario visualisation
Water quality indicator values and water velocity
Model scenario visualisation

Viewing KML version of water quality results in Google Earth
Discussion and evaluation
Advantages and limitations of our approach

Advantages of using the open-source “GeoStack”

• Allows layers to be streamed in real-time to the Web browser.
• Latency is minimised by pre-generating and caching images.
• Transfer time minimised through the use of compressed PNG images.

Support for user interactivity

• Allows model scenarios to be “run”, despite being cached.
• Ability to pan, zoom, and animate results.
• Displays indicator trend graphs for any location.
• Enables users to better compare scenarios and management actions.

Limitations of this approach

• Grid elements in the data model only supports a two-dimensions.
• Fixed resolution of grid elements less flexible that finite element mesh.
• Does not communicate uncertainty estimates associated with results.
Conclusions and future work

Current functionality and potential extensions

What we’ve demonstrated

- Online information system that extends the open source GeoStack.
- Hydrological modelling results are transformed, stored, described, and made accessible via a Web interface to a PostgreSQL database.
- Provides high-speed interactive access to hydrological models.
- We believe that this approach represents a comprehensive technological framework for online sharing of hydrological models with non-technical decision makers and other stakeholders.

Future work

- Core aspects applicable to other spatio-temporal models.
- Could be adapted to include more complex hydrological models, particularly the new version of RWQM, in three dimensions.
- Adaptation of data processing software to utilise cloud computing facilities that further accelerate data processing.
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