Spatial hydrology
Methods and tools to evaluate the impact of natural and anthropogenic artefacts on runoff pathways

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Outline

- Introduction
- Drainage network
  - Raster-based approach
  - TIN-based approach
- What about human-made features?
- TANATO
Introduction

• Increase of urbanization, landscape changes

Today more than half of the globe’s population live in towns and cities.

Urban areas: fast expansion

Since 1950, on average the growth of built-up areas has been 87% in 15 European urban areas (Kasanko et al, 2006)

from 28% in Vienna to 220% in Palermo

Environmental impacts (EEA 2006, SACTRA 1995)
Introduction

- consumes land soil,

- reduces the land biodiversity (natural and protected areas) consumed directly by construction and infrastructure,

- induces demands for raw materials typically produced in remote location and requiring transportation,

- transport related energy consumption, pressure on natural and protect areas

- transforms the properties of soil, reducing its capacity to perform its essential functions (discharge, recharge, water and atmospheric pollution, flood..)
Introduction

• Water cycle and runoff pathways

+ decrease in the volume of water that percolates into the ground,
+ decrease in quality of surface water.

These hydrological changes have significant implications for the quantity of clean water that is available for use by humans, fish and wildlife.

Linear landscape features (tillage, hedgerow, road, ditches and culvert) influence the flow networks (runoff) and erosion patterns (Montgomery, 1994; Ludwing et al, 1996; Souchere et al, 1998; Tague and Band, 2001; Bocher, 2008...).
Introduction

Talus

Stop – change, enforce direction – accumulation

Tillage

Road and ditch

Road

Bocher, 2005

Delahaye, 2002

Duke et al., 2003

InfoClimat, 2009

Spatial hydrology – Bocher & Petit
Open Source Opportunities in GIS – Summer School. Girona 2010
Introduction

- A focus on spatial hydrology

Petts (1995) suggests that the start of the “modern” geographical to channel hydrology was founded by Strahler (1952).

Source: wikipedia
Introduction

Two mains evolution:

in the computer power,

high-resolution digital elevation models (DEM).

Identification of drainage pathways (flow routing)
Drainage network

• General definition

Drainage network can be considered as an oriented graph which each cells are connected on which the topographic data is structured.

A drainage network is spatially distributed.
Drainage network

• Raster-based

1. Grid direction: D8, Multiple flow, D infinity (Fairfield and Leymarie, 1991; Quinn et al., 1991; Costa-Cabral and Burger, 1994, Tarboton 1997...).

2. Grid accumulation and 3. River extraction.

![Diagram showing DEM, Direction, Accumulation, and River extraction processes.]
Drainage network

- Raster-based (examples)

DEM → Grid direction
Drainage network

- TIN-based

A set of triangles, nodes and arcs connected.
Yu et al., 1996; Tucker et al, 1999; Petzold, 2001...
Drainage network

- TIN-based (example)

Source: http://duff.ess.washington.edu/tins/index.html
Human made features impact

- Raster approach


Raster road impact

Roads rasterization process

Pixels accumulation
TIN approach

Why TIN is better?
- No constant spatial resolution,
- No direction approximation, explicit surface,
- Topological rules for each feature.
TIN approach

Source: Bocher, 2005
TIN approach

- Tucker et. al, 2001, tRIBS (TIN-based Real-Time Integrated Basin Simulator)
  - Soils,
  - Land Use,
  - Rainfall radar,
  - Hydrological simulator.

- Delahaye et al (2001), RuiCells
  - Land Use (run-off indexes with Cellular Automata).

- Bocher (2006, 2008), Bocher and Bedel (2007), Bocher et Martin (2010), TANATO
  - Complexe runoff drainage network with :
    - Land Use (runoff index),
    - Road,
    - Hedgerow, wall,
    - Ditch network.
    - Bridge.
TANATO

- Introduction

TANATO is a TIN-based (Triangular Irregular Network) model to evaluate the effect of agricultural practices and human-made features such as hedgerow, road, sewer and parcels on the runoff pathways.

TANATO is a spatially distributed model coupled with CAM (Cellular Automaton Machine).
TANATO

- Features and data input

A geometry contains an array of x, y and z coordinates.
• Features and data input (quality analysis)

Data quality is controlled using the 9I matrix (Egenhofer, 1993) to identify topological spatial relations.
TANATO

- Constrained 3D TIN (4 steps)
  Step 1: Compute a constrained delaunay triangulation using elevation data. During this step flat triangles are removed based on the skeleton method.

TIN

TIN without flat triangles
TANATO

- Step 2:
  Insert into the elevation TIN rivers, ditches, parcels and roads as constrained features. During this step, nodes, edges and triangles are marked with a constrained type value:
  type.parcel, type.road, type.river, type.ditch
TANATO

• Step 3:
  Insert into the TIN 2 the sewer network.
  • Input sewer (added over the TIN)
  • Intermediate point with a Z value under the Z DEM
  • Output sewer (added in the TIN)
• Step 4: 
  Insert bridge as a 3D object.
The final TIN is stored in 3 separated files that describes topological relations. They are used to compute a graph.

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TANATO

Parcels

Hedgerows

Rivers

Countour lines
TANATO

- Graph network

Flow paths over the TIN surface is computed using the steepest lines of descent of TIN faces.

Ridge  Talweg  Right slope
TANATO

- Graph network
TANATO

- Outputs
  - Watershed delineation,
  - Runoff paths,
  - Cells surface accumulation,
  - “Surfacogramme” (computer iteration)
  - Normalized width function.
TANATO

Watershed with ditch constraints

Watershed with a contour lines TIN

Outlet
TANATO

- Implementation

Tanato2 is a GPL plug-in of OrbiGIS.

Tanato is a set of SQL spatial functions based on the GDMS language.

For example:

To Create a TIN:

SELECT ST_BuildTIN(the_geom, true) FROM myContourLines;

Where the_geom is a line or polyline with x,y, z coordinates true to remove flat triangles
Synthesis

• TANATO is under test on the Chezine bassin (Nantes, France). It will be applied in august on the Mercier Sub-watershed (Lyon, France).

• TANATO is available at :
http://geosysin.iict.ch/irstv-trac/browser/branches/libs/tanato

The Delaunay library :
http://geosysin.iict.ch/irstv-trac/browser/branches/libs/jdelaunay

It can be tested following this URL :
http://geosysin.iict.ch/irstv-web/jws/orbisgis.jnlp

DEMO