Enhanced DEM-based flow path delineation algorithms for urban drainage modelling

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Urban Flood Modelling (UFM)
Dual-drainage concept
DEM and overland flow path delineation
**DEM and overland flow path delineation problems**
Advanced flow path delineation methods
Results
Conclusions
Urban pluvial flooding (background)

Extreme rainfall events!

Poors drainage management
Overloaded drainage system

Processes on the surface
Ponds developing;
Moving over long distance using preferential routes (streets, canals);
Interacting with subsurface (sewer) system.
Need for advanced urban drainage models
Dual-drainage concept

Dual-drainage concept (1D/1D and 1D/2D)

Sewer system (manholes and pipes).

Overland system (depressions and flow paths).

1D overland flow modelling

Overland system consists of nodes (ponds) and links (flow paths), generated using DEM.

2D overland flow modelling

Surface divided into small elements (squares or irregular triangles), the flow equations (St. Venant) are based on terrain characteristics derived from the DEM.
DEMs and overland flow path delineation

DEMs availability
SRTM | Contour | Photogrammetry | InSAR | LiDAR | Truth surveys

(increasing accuracy and resolution)

DEM errors
can be due to errors during the elevation acquisition techniques, interpolation methods, etc…

Pit cells and flat areas (they can also be real terrain features)

DEM resolution and urban pluvial flood modelling
Between 1 and 5m (in order to represent the urban features, such as buildings, street curbs)
DEM errors ➔ Flow path delineation problems

Conventional flow path delineation algorithms stop when a pit cell or a flat area is reached.
Flow path delineation algorithms

Rolling ball algorithm (Prodanović, 1999)
Flow path completeness problem

Bouncing ball algorithm (Boonya-aroonnet et al., 2007)
Urban features crossing problem

Three advanced approaches to solve the two problems of conventional algorithms are proposed:
Bouncing ball and buildings algorithm
Bouncing ball and A* algorithm
Sliding ball algorithm
Synthetic Digital Elevation Model

150 columns and 100 rows
1 obstacle to the flow (building)
1 flow path starting point
Results obtained using the conventional methods

**Rolling ball algorithm** (Prodanović, 1999)
Flow path **stops** near the building (pit cell) – **incomplete** flow path
This method is not appropriate to urban areas where buildings and other man-made features can create small pit cells

**Bouncing ball algorithm** (Boonya-aroonnet et al., 2007)
Flow path continues after the small pit cell
But flow path **crosses a building**, i.e. representation of the flow path is **not realistic**
Results and discussion

*Bouncing ball and buildings* algorithm

Flow path *does not stop* near the building (pit cell)

Flow path *does not cross* the building

But, flow path is *significantly diverted* from the building: is this what is reported in reality???
**Results and discussion**

*Bouncing ball and A* algorithm*

Flow path *does not stop* near the building

Flow path *does not cross the building*

AND flow path *goes around the building*!

this result seems similar to what is observed in reality!!!
Results and discussion

Sliding ball algorithm
Flow path does not stop near the building

Flow path does not cross the building

And flow path goes around the building!

The result obtained using the algorithm is identical to that obtained using the Bouncing ball and A* algorithm

The difference is associated with the different way the algorithms work
Results and discussion

What is the best algorithm?
There is no best algorithm but...

The three advanced algorithms presented guarantee the completeness of the flow path delineation and avoid crossing obstacles

<table>
<thead>
<tr>
<th>Flow path delineation algorithm</th>
<th>Length (m)</th>
<th>Complete?</th>
<th>Cross obstacle?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling ball</td>
<td>64.3</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Bouncing ball</td>
<td>148.7</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Bouncing ball and buildings</td>
<td>155.9</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Bouncing ball and A*</td>
<td>157.8</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sliding ball</td>
<td>173.9</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Case-study (preliminary results)

**Location:** Lisbon (Portugal)

**Area:** approx. 100ha

**Land use:** highly urbanised
Case-study (preliminary results)

(a) Bouncing ball
(b) Bouncing ball+buildings
(c) Bouncing ball+A*
(d) Sliding ball
Case-study (preliminary results)

Rolling ball  (a) Bouncing ball  (b) Bouncing ball+buildings
(c) Bouncing ball+A*  (d) Sliding ball
Conclusions

Urban Flood Modelling
Need to accurately consider surface water phenomena
DEM can be used to support such models (1D or 2D models)

DEM availability and resolution
High-resolution DEMs (e.g. LiDAR) are becoming increasingly available
Highest resolution means higher number of DEM errors (pit cells and flat areas)

DEM-based flow path delineation algorithms are severely affected by DEM errors
Flow path delineation stops if a pit cell or flat area is reached
Urban features (e.g. buildings, etc.) can halt the flow delineation process
Conclusions

Advanced flow path delineation algorithms
Three novel improvements were developed

The results obtained (with synthetic case) and the initial results obtained with one real case show significant improvements

Completeness problem of flow path is solved

Flow paths crossing urban features problem is also worked out
Enhanced DEM-based flow path delineation algorithms for urban drainage modelling

Thank you for your attention

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