Hydrographic network extraction

P-A. Ayral, D. Maréchal, J-S. Bailly, C. Puech, S. Sauvagnargues
Use of Very High Resolution (VHR) satellite imagery for the study of the morphologic origin of water pathways on small Mediterranean catchments subjected to flash floods

PhD thesis staff:
EMA: Sophie Sauvagnargues et Pierre-Alain Ayral
IRSTEA: Christian Puech et Jean-Stéphane Bailly

CNES → ORFEO Program:
- Potentialities of PLEIADES imagery
- Methods for data analysis

→ Applications on floods
INTRODUCTION

• Context:
  Mediterranean « flash floods » during autumn season

• Events are:
  • hard to forecast
  • hard to study
  • hard to monitor

→ Knowledges on catchments hydrology during floods

Spatio-temporal variability of waterpathways during rainfall episodes
(Ambroise, 1999; Moussa, 2009; Braud, 2010)
INTRODUCTION: Issue

1. Study spatio-temporal variability of hydrologic responses

2. Analyse influence of catchments and networks morphologies

- Objects of focus: hydrographic networks:

How surface flows are generated and canalized during rainfalls?

- VHSR satellite imagery and hydrographic networks:
  → Method of delineation / characterization?

- Catchments and networks’ morphologies:
  → Influence on hydrological dynamics?
INTRODUCTION: approach

Potential Drain
(Morphology)

- Remote sensing & spatial analysis
- Thalwegs extraction by DEM analysis

Real Drain
(Surface water flow)

- Field work
- Hydrological measures and observations
  (permanent / events monitoring)

Water loading in morphological network

⇒ Enhancement of knowledges on hydrological processes
INTRODUCTION: study area
1. Potential drain:

   Method for the delineation of the potential drain from DEM

2. Potential drain:

   Results on experimental catchments

3. Conclusion
1. Potential drain: why a new algorithm?

Development of NET algorithm: enhance actual algorithms

1. Extract potential network $\rightarrow$ morphological analysis

• Avoid drained area threshold determination

• Provide morphological features

2. Enhance flow directions tracing and networks extraction
1. Potential drain: method for network delineation: data

Choice of the TIN structure (Nelson, 1999; Tucker, 2001; Vivoni, 2004)

- Direct triangulation of elevation data from satellite stereoscopic analysis (PLEIADES)
  - Avoid square grid interpolation
  - Reduce data amount (Very High Spatial Resolution)

Delaunay triangulation: optimised triangulation, gives more compact triangles
1. Potential drain: method for network delineation: data

Original data:
LIDAR TIN DEM: 1m resolution

TIN used:
12m resolution

Degradation
To fit PLEIADES DEM resolution

Cartaou catchment

1. Potential drain  2. Results  3. Conclusion
1. Potential drain: steps of NET algorithm

- **Preprocessing**
  - TIN creation from LIDAR data
  - Edges orientation following the slope
  - Avoid fake convergence of surface flows, avoid disconnection of the networks
  - Delineate local morphologies: thalwegs, crest and type of slope (decreasing or increasing)
  - Allows facet crossing in multiple directions, refined drainage direction on slopes, refined drained areas: drainage tree establishment
  - Reconnected thalwegs with drainage tree: Potential drain

- **Calculation of drained areas**
  - Calculation of drained areas for each points of the refined mesh

- **Hydromorphological calculation**
  - Calculation of hydromorphological parameters on the final network
1. Potential drain: edges delineation

1: Thalweg    2: Ridge    3: Slope increasing    4: Slope decreasing
1. Potential drain: drainage direction

Ternary and quaternary refinement (De Floriani et al., 1984 et Gomez et al., 1979)

O way to cross facets 10 different ways to cross facets

Drainage tree
1. Potential drain: talweg network

- Morphological analysis $\rightarrow$ disconnected thalweg
  (Tribe, 1992)

$\rightarrow$ Reconnection:

-Disconnected thalwegs are reconnected with drainage tree

![Network of Reconnected Thalwegs (NRT)](image)

- Points of the densified TIN
  - Thalwegs edges
  - Drainage tree edges

1. Potential drain  2. Results  3. Conclusion
2. Results on experimental catchments

NRT: quantitative evaluation

Morphological analysis

Flow directions

Caractérisation morphologique

- crête
- thalweg

Surface amont drainée (m³)

- 0.0 - 1090.0
- 1095.0 - 5033.1
- 5033.1 - 12584.4
- 12584.4 - 24959.4
- 24959.4 - 41968.8
- 41968.8 - 60675.0
- 60675.0 - 109601.6
- 109601.6 - 255198.4
- 255198.4 - 361135.9
- 361135.9 - 691918.8

Ridge

Talweg
2. Results on experimental catchments

NRT : quantitative evaluation

Reference network: Photo-interpreted on LIDAR DEM
2. Results on experimental catchments
   NRT : quantitative evaluation

→ 2 indexes (in percent of the total length):
   - FND : omission
   - FPD : over detection

Dt: Total difference (FPD + FND)
De: Differences equilibrium (FPD – FND)

<table>
<thead>
<tr>
<th>Bassin</th>
<th>L (m)</th>
<th>FPD</th>
<th>FND</th>
<th>Dt</th>
<th>De</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartaou</td>
<td>10978</td>
<td>25,5</td>
<td>24,1</td>
<td>49,6</td>
<td>1,4</td>
</tr>
<tr>
<td>Crébadès</td>
<td>14584</td>
<td>31,4</td>
<td>17,2</td>
<td>48,6</td>
<td>14,2</td>
</tr>
</tbody>
</table>

NET extracts > 50% of the reference network (1-Dt)

→ NET ability to extract potential networks from limited amount of data
2. Results on experimental catchments
Comparison of drainage network

1. Potential drain  2. Results  3. Conclusion
2. Results on experimental catchments
Evaluation of raster based extractions

Réseau DEMON

Réseau Dinfinity

Réseau D8

NRT

1. Potential drain  2. Results  3. Conclusion
## 2. Results on experimental catchments

**Evaluation of raster based extractions**

<table>
<thead>
<tr>
<th>Methods</th>
<th>L</th>
<th>Dt</th>
<th>De</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartaou</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D_\infty$</td>
<td>9950</td>
<td>56,7</td>
<td>7,5</td>
</tr>
<tr>
<td>D8</td>
<td>10652</td>
<td>62,5</td>
<td>7,3</td>
</tr>
<tr>
<td><strong>NET</strong></td>
<td>10978</td>
<td><strong>49,6</strong></td>
<td><strong>1,4</strong></td>
</tr>
<tr>
<td>DEMON</td>
<td>12988</td>
<td>57,6</td>
<td>23,4</td>
</tr>
<tr>
<td>Crébadès</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D_\infty$</td>
<td>11984</td>
<td>61,3</td>
<td>3,8</td>
</tr>
<tr>
<td>D8</td>
<td>13064</td>
<td>60,7</td>
<td>8,2</td>
</tr>
<tr>
<td><strong>NET</strong></td>
<td>14584</td>
<td><strong>48,6</strong></td>
<td><strong>14,2</strong></td>
</tr>
<tr>
<td>DEMON</td>
<td>14538</td>
<td>60,7</td>
<td>19,6</td>
</tr>
</tbody>
</table>
2. Results on experimental catchments

Network of Reconnected Thalwegs: outcomes

- NET refines flow directions and networks traces
  → TIN structure & densification of the mesh

- NET better fits the reference network
  → Combining morphological analysis & flow directions methods

- Avoid threshold determination

- Use of remote sensing elevation data
  - Direct triangulation of elevation points
  - Generalisation

- NET provides morphological features
4. Conclusion

1. An original algorithm for network extraction on TIN

2. A Complete description of hydrological responses
   → Space: distributed monitoring / Time: event based monitoring
   → Types of responses: discharges, active networks

3. A first approach of link between potential and real drain

Prospects

To improve the NET algorithm (generalization, resolution/scale analysis)

To improve the preprocessing of NET

To implement NET on the ORFEO Tool Box

Integration of results into distributed hydrologic models
The phD Thesis of Denis Maréchal (in french):


dens.marechal@gmail.com
pierre-alain.ayral@mines-ales.fr

About NET


About the hydrological approach

Hydrographic network extraction

P-A. Ayral, D. Maréchal, J-S. Bailly, C. Puech, S. Sauvagnargues