TRENT2D WG: A SMART WEB INFRASTRUCTURE FOR DEBRIS-FLOW MODELLING AND HAZARD ASSESSMENT

Nadia Zorzi\textsuperscript{(1)}, Giorgio Rosatti\textsuperscript{(1)}, Daniel Zugliani\textsuperscript{(1)}, Alessandro Rizzi\textsuperscript{(2)}, Stefano Piffer\textsuperscript{(2)}

\textsuperscript{(1)} University of Trento
CUDAM – University Center for Advanced Studies on Hydrogeological Risk in Mountain Areas
DICAM – Department of Civil, Environmental and Mechanical Engineering

\textsuperscript{(2)} Trilogis Srl
Research & Development Lab

Tuesday, 19\textsuperscript{th} April 2016
OUTLINE

- Debris flows
- The Directive 2007/60/EC as a mission
- The model TRENT2D
- SaaS approach and WebGIS technology
- TRENT2D WG: a web integrated solution

MAIN REFERENCES:


DEBRIS FLOWS

 rio Monzoni TN, Italy: 1 Aug 2012 - by Adriano De Silvestro

Video: Adriano Desilvestro (www.youtube.com/watch?v=aKm6zUaTr_s)

✓ Two-phase granular flows
✓ High concentration
✓ Significant morphological modifications

Photo: Autonomous Province of Trento

COMPLEX AND HAZARDOUS PHENOMENA

Debris flows Directive 2007/60/EC TRENT2D SaaS and WebGIS TRENT2D WG
The Flood Directive 2007/60/EC provides:

**GOAL**

It is feasible and *desirable* to *reduce* the risk of adverse consequences.

**METHOD**

[Hazard and risk] assessment, maps and plans should be based on appropriate best practice and best available technologies not entailing excessive costs.

**SAFETY = SOCIAL NEED**

**COMPLEX PHENOMENA**

**STATE-OF-THE-ART MODELS**

Hazard and risk assessment, maps and plans should be based on appropriate best practice and best available technologies not entailing excessive costs.
THE DIRECTIVE 2007/60/EC AS A MISSION

Obstacles

- High complexity + large computational burdens
- Research tool
- Stand-alone software logic

- High investment of resources (hardware, time)
- Not user-friendly
- Hard maintenance
- Weak connection researchers-users
- Fragmentation
- Low interoperability
THE TRENTO2D MODEL

TRENT2D
Transport in Rapidly Evolutive, Natural Torrent – 2D

- 2D
- Shallow flow
- Mobile bed
- Two-phase mixture
- Isokinetic description
- Immediate adaptation

Closure relations
✓ $c \propto Fr^2$  
   [Rosatti and Fraccarollo, 2006]
✓ $\tau_b$: grain-inertial regime  
   [Takahashi, 1978]

\[
\begin{align*}
\frac{\partial}{\partial t} (z_b + h) + \frac{\partial}{\partial x} (hu_x) + \frac{\partial}{\partial y} (hu_y) &= 0 \\
\frac{\partial}{\partial t} (c_b z_b + ch) + \frac{\partial}{\partial x} (chu_x) + \frac{\partial}{\partial y} (chu_y) &= 0 \\
\frac{\partial}{\partial t} ((1 + c\Delta)hu_x) + \frac{\partial}{\partial x} ((1 + c\Delta)(u^2 h + \frac{1}{2} gh^2)) + \frac{\partial}{\partial y} ((1 + c\Delta)hu_x u_y) + (1 + c\Delta)gh \frac{\partial^2 z_b}{\partial x^2} &= -\frac{\tau_{bz}}{\rho_v} \\
\frac{\partial}{\partial t} ((1 + c\Delta)hu_y) + \frac{\partial}{\partial x} ((1 + c\Delta)hu_x u_y) + \frac{\partial}{\partial y} ((1 + c\Delta)(u^2 h + \frac{1}{2} gh^2)) + (1 + c\Delta)gh \frac{\partial^2 z_b}{\partial y^2} &= -\frac{\tau_{by}}{\rho_v}
\end{align*}
\]

Numerical model
✓ Cartesian mesh
✓ Finite-volume method
✓ Godunov-type fluxes
✓ Second-order accuracy in space and time
THE TRENT2D MODEL

Geographic data

Hydrological data

Computational domain

Boundary conditions

Maps (governing variables)

Zorzi et al. – TRENT2D WG: a smart web infrastructure for debris-flow modelling and hazard assessment
**SAAS APPROACH AND WEBGIS TECHNOLOGY**

**SaaS = Software as a Service**

- Cloud server
- Accessible via Web
- Suitable GUI

**WebGIS**

= *Web application able to manage, display and process geographic and economic data* [Plewe, 1997]

- GIS functionalities
- High flexibility
- Wide potential [De Amicis et al., 2009]
SAAS APPROACH AND WEBGIS TECHNOLOGY

- High investment of resources (hardware, time)
- Non user-friendly
- Hard maintenance
- Weak connection researchers-users
- Fragmentation
- Low interoperability

→ High-performing cloud server
→ Intuitive
→ No installation
→ Centralised maintenance
→ Stronger connection researchers-users

GIS functionalities
TRENT2D WG

TRENT2D (as a Service) + WEBGIS = TRENT2D WG

Available on trent2d.trilogis.it

\[
\begin{align*}
\frac{\partial}{\partial t} (zh + h) + \frac{\partial}{\partial x} (hu_x) + \frac{\partial}{\partial y} (hu_y) &= 0 \\
\frac{\partial}{\partial t} (c_h z_h + ch) + \frac{\partial}{\partial x} (chu_x) + \frac{\partial}{\partial y} (chu_y) &= 0 \\
\frac{\partial}{\partial t} ((1 + c\Delta)hu_x) + \frac{\partial}{\partial x} ((1 + c\Delta)(u_x^2 h + \frac{1}{2}gh^2)) + \frac{\partial}{\partial y} ((1 + c\Delta)hu_y) + (1 + c\Delta)gh \frac{\partial^2 h}{\partial x^2} &= -\frac{\tau_{xx}}{\rho_v} \\
\frac{\partial}{\partial t} ((1 + c\Delta)hu_y) + \frac{\partial}{\partial x} ((1 + c\Delta)hu_x u_y) + \frac{\partial}{\partial y} ((1 + c\Delta)(u_y^2 h + \frac{1}{2}gh^2)) + (1 + c\Delta)gh \frac{\partial^2 h}{\partial y^2} &= -\frac{\tau_{yy}}{\rho_v}
\end{align*}
\]
TRENT2D WG

System architecture

MULTI-TIER ARCHITECTURE

Application Layer

Middleware Layer

Data Layer

Information display

Complex processing (Trent2D, Geo Server, Hazard Mapper...)

Data storage and retrieving

In keeping with OGC® standards

Debris flows Directive 2007/60/EC TRENT2D SaaS and WebGIS TRENT2D WG
TRENT2D WG

Pre-processing

- Create/manage computational domains
- Define inflow sections
- Define boundary conditions
- Prepare new simulations
- ...

TRENT2D

New simulation:
- Name: test
- Description: notes about the simulation "test"
- Type: Debris flow
- Ks (*,asc):
  - 30_GrandValley
  - 100_GrandValley
  - 200_GrandValley

Pre-processing:
- Create/manage computational domains
- Define inflow sections
- Define boundary conditions
- Prepare new simulations
- ...

Director 2007/60/EC

Debris flows

SaaS and WebGIS

TRENT2D
TRENT2D WG

Post-processing

✓ 2D local view
✓ 2D global view
✓ 3D view
✓ ...
TRENT2D WG

Hazard Mapper

Wizard

TRENT2D

HAZARD MAPPER

In keeping with BUWAL standards
[Heinimann et al. 1998]
**CONCLUSIONS AND FUTURE DEVELOPMENTS**

**TRENT2D WG**

*a smart web infrastructure for debris-flow modelling and hazard assessment*

---

**Future developments**

- The TRENT2D model
  - Fixed-mobile bed
  - Closure relation for concentration

- The TRENT2D WG system
  - New functionalities
  - A rainfall-runoff model
  - Other models as services

- ✔️ Hazard assessment
- ✔️ Design of protection measures
- ✔️ Back-analyses
THANK YOU FOR YOUR ATTENTION

ARE YOU INTERESTED? Register on trent2d.trilogis.it

This modelling solution was partially realized within two research projects: the CLIMAWARE project, funded by the University of Trento (Italy), and the MHYMESIS project, funded by the CARITRO Foundation (Italy).