ITALIAN NATIONAL RESEARCH COUNCIL
RESEARCH INSTITUTE FOR GEO-HYDROLOGICAL PROTECTION
EVALUATION OF THE PARALLEL PERFORMANCE OF THE TRIGRS v2.1 MODEL FOR RAINFALL-INDUCED LANDSLIDES

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OUTLINE

• The TRIGRS Model
  - Basics of the Model
  - Possible Uses of TRIGRS

• Why Parallel Processing
  - Choice of Parallelization Strategy
  - Aims of Parallel Processing

• Parallel Performance of TRIGRS
  - Commercial Hardware
  - High-Performance Machines
  - Cloud Environment (OpenStack)
PHYSICALLY-BASED MODEL FOR THE ASSESSMENT OF SLOPE STABILITY AGAINST RAINFALL-INDUCED SHALLOW LANDSLIDES → FACTOR OF SAFETY

 Baum et al (2008); Alvioli and Baum (2016)
TRIGRS AND Rainfall Thresholds

For individual slopes, using TRIGRS we calculate the fraction of failing cells as a function of storm duration and intensity to build I-D thresholds.

Rainfall thresholds produced by TRIGRS are comparable to empirical ones.

Alvioli et al. (2014)
TRIGRS AND LANDSLIDE SIZE

WE RECOVER WITH TRIGRS THE SIZE DISTRIBUTION OF OBSERVED LANDSLIDE SIZE, FOR VARIOUS INTENSITY/DURATION COMBINATIONS

Alvioli et al (2014)
“Physically based” implies:

- **Quantitative approach, computing-intensive**

- **Cell-by-cell calculations, independent cells**

- **Gridded data in input & output of variable size → variable computing time**
**Parallel Processing Strategies**

**In General**
- General purpose software applications
- Distributed Computing
- Languages implementing low-level parallel libraries in a generic way (Python, R, ...)
- Source C / FORTRAN code: use of low-level parallel libraries (MPI, OpenMP, CUDA, ..)

**At CNR IRPI**
- GRASS GIS: scripting allows parallel (distributed) execution
- The same problem can be solved in its entirety or in many, small pieces
- r.slope.stability for deep-seated landslides
- TRIGRS for shallow landslides
Why Parallel Processing?

Reduced Computing Time AND/OR
Simulations on Larger Areas

TRIGRS

\[ \text{Speedup} = \frac{T_1}{T_N} \]

Alvioli and Baum (2016)

TRIGRS Parallel Performance

Mergili et al (2014)
**MULTIPLE RUNS: PROBABILISTIC APPROACH**

We define Probability Distribution Functions (PDFs) of geo-technical parameters based on field measurements and lab analysis.

Optimal values of cohesion and friction angle much smaller than PDF mean (TRIGRS and r.slope.stability)!

Why FORTRAN?

• Modern FORTRAN compilers produce codes that are as fast as they can get.

• Scientific applications are easily coded - steep learning curve – a lot of existing code.

• *High Performance Computing fully supports C, C++ and FORTRAN: OpenMP, MPI*

• Most high-performance applications are actually coded in FORTRAN.
**RUNNING TIME GAIN (SINGLE-NODE)**

![Graph showing TRIGRS parallel performance]

- **$T_{Tot}$**: Total running time.
- **$T_W$**: Time spent on writing.
- **$T_R$**: Time spent on reading and scattered input data.
- **$T_C$**: Time spent on core computations.

**Overview**
- **$N_p$**: Number of processes.
- **$t_1$, $t_2$, $t_3$, $t_4$**: Times for different stages of execution.
- **Read + Scatter**, **Core + Gather**, **Write**: Stages of data processing.

**Analysis**
- The graph illustrates how the running time changes with the number of processes, showing the gain in performance with parallel execution.

**Conclusion**
- The TRIGRS parallel performance exhibits significant gains with an increase in the number of processes, optimizing the time spent on various stages of computation and data handling.
**RUNNING TIME GAIN (HPC MULTI-NODE)**

Single-Node vs. Multi-Node

- **Single-Node**: 64-core machine
- **Multi-Node**: Galileo @ CINECA

![Graph showing running time gain comparison between single-node and multi-node systems](image)
RUNNING TIME GAIN (CLOUD)

(A) Total Running Time

- Single-Node: 64-core machine
- Multi-Node: Galileo @ CINECA
- Cloud: OpenStack @ CERN
**SPEEDUP: SINGLE-NODE VS. MULTI-NODE**

- **Single-Node**: 64-core machine
- **Multi-Node**: Galileo @ CINECA
Dependence on problem size

The largest problem size was 26,800,000 cells

Alvioli and Baum (2016)
CITED REFERENCES:


- **M. Alvioli, F. Guzzetti, M. Rossi** – *Scaling properties of rainfall-induced landslides predicted by a physically based model* – Geomorphology 213 (2014) 38


- **M. Mergili, I. Marchesini, M. Alvioli, M. Metz, B. Schneider-Muntau, M. Rossi, F. Guzzetti** – *A Strategy for GIS based 3D slope stability modelling over large areas* – Geosci. Model Dev. 7 (2014) 2969

**Conclusions**

- TRIGRS v2.1 was parallelized **using MPI**
- The model is a widely used one, and changes to the code are **transparent to the user**
- We tested the parallel performance on commercial hardware, a high-performance machine, OpenStack cloud environment
- **Substantial improvement** on desktop machines
- HPC machines \(\rightarrow\) simulate large scale
- Cloud environment: needs fine-tuning
SOFTWARE IS
AVAILABLE FOR DOWNLOAD AT:

• Parallel TRIGRS:
  http://geomorphology.irpi.cnr.it/tools/trigrs

• r.slope.stability:
  http://www.slopestability.org

Thank you!