STOCHASTIC MODELLING OF FLUVIAL MORPHODYNAMICS

Bruno Oliveira
STOCHASTIC NUMERICAL MODELLING OF FLUVIAL MORPHODYNAMICS

GOAL

METHODOLOGY FOR STOCHASTICALLY GENERATING MODEL INPUT

EXISTING NUMERICAL HYDRODYNAMIC AND MORPHODYNAMIC MODELS

Bruno Oliveira / Stochastic Modelling of Fluvial Morphodynamics
Main Objectives

1st priority: Creation
Application
Validation

2nd priority: Development of Numerical Models
- Time Series Generation Technique
  - Output: Multiple Streamflow Time Series
- Initial Bathymetry
- Hydro- and Morphodynamic Models
  - Output: Multiple Sets of River Bathymetry
- Statistical Code Module
  - Output: Probability Distribution Function of River Evolution

3rd priority: Application and Validation of Numerical Models

4th priority: Sensitivity Analysis, Characterization of Bed Change and Application
Work Plan

- Collection of in-situ information from case study(ies)
- Collection of historical records
- Stochastic Series Generation
- Development of the hydro-metamorphic models
  - Model Selection and Integration
- Application of the methodology
- Sensitivity analysis
  - Analysis of...
  - Etc.
- Statistical characterization of morphodynamics
- Risk Analysis

And now... Defense!
Statistical Characterization of Morphodynamics (Mondego River)

Case study reach

Specific section(s):
- Erosion magnitude
- Erosion profiles
Risk Analysis (Case Study)

Estimating $P(x)$, where $x$ is:
- Rotational failure
- Block failure
- Slide failure

Failure costs/scenarios:
- Complete bank rehabilitation
- Full bank protection
- Active monitoring/rehabilitation

$P(\%) \times C (\€) = RISK$
Risk Analysis (Stability Analysis)

Retention wall situated 20 meters from the river:
- Necessary for N110 road
- Steep implantation slope
- Situated at an exposed edge of the road (due to curvature)
Risk Analysis (Stochastic Modelling)

Included
- 10 values of Shear Angle
- 10 values of Dry Density of Soil
- 10 values of Dry Density of Landfill
- 25 selected erosion profiles
- 140 rotational centres
- Av. 5 radius per centre

≈ 17.5 Mil. Limit State Analysis

For the 1Y and 2Y horizons

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Distribution</th>
<th>Parameters</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Angle</td>
<td>$\Phi_r$</td>
<td>Uniform</td>
<td>34, 38</td>
<td>$^\circ$ (degrees)</td>
</tr>
<tr>
<td>Dry Density of the soil</td>
<td>$\gamma_s$</td>
<td>Uniform</td>
<td>20, 22</td>
<td>KN/m$^3$</td>
</tr>
<tr>
<td>Dry Density of the landfill</td>
<td>$\gamma_{wall}$</td>
<td>Uniform</td>
<td>21, 23</td>
<td>KN/m$^3$</td>
</tr>
</tbody>
</table>
Risk Analysis (Stochastic Modelling)

Failure mechanisms for rotational failure:

Using the simplified Bishop method, each failure surface corresponds to a safety factor:

(block and slide failure are uncommon in the context of morphodynamics)
Risk Analysis (Failure Likelihood)

Transformed into a probability distribution of failure as a function of the critical safety factor:

Considering a geometrical decay of the failure likelihood (from bank stabilization):
Risk Analysis (Application)

Adding the expected costs from:
• Bank protection (40 000 €)
• Bank and wall repair (160 000 € on collapse)
• Active Monitoring & Rehabilitation (15 000 € + 3 000 €/yr)

And the corresponding likelihoods:
Finished Products

Thesis

Publications:

- Stochastic Generation of Streamflow Time Series
- Pre-modelling as tool for optimizing morphodynamical numerical simulations
- Sensitivity Analysis of Fluvial Morphodynamics

Other papers underway...

Manual:

“APPLICATION METHODOLOGY FOR THE STOCHASTIC MODELLING OF FLUVIAL MORPHODYNAMICS”
Summary

The journey

The stochastic modelling methodology was developed from the generation input to the analysis of the output

The Validation

Sensitivity analysis is useful for the validation of stochastic modelling (at least for pairwise comparisons)

The Importance

Morphodynamics are important for near-bank stability (estimated failure likelihoods exceed one percent)

The Future

Morphodynamics displayed a clear statistical spatial structure (for generalization and extrapolation)
Questions: More or Less?

About the stochastic modelling:

• Would simulating a large number of quantile-matched values of the variables be equivalent to Crude Monte Carlo? Which is more efficient?
• Can the results of the simulations be extrapolated (i.e., convoluted) over time? Globally or Locally?
• What are the best probability distributions for morphodynamical quantities? (namely for extreme, localized and global values)

About Reliability and Risk Analysis

• How significant are the errors introduced by the applied interpolation?
Thank you for your attention!

The End