Verzasca Flash Flood Prediction

Team 4 – AIM2016, ETH Zurich
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Flash floods – danger for people

https://youtu.be/N6tiolDy0bA
Flooding process

• Input:
  • Rainfall data (radar)
  • Topography

• Model:
  • Runoff on slopes
  • Accumulation in river
  • River runoff

• Output:
  • Measurements at station

• Goal:
  • Prediction of water height at any location
  • statistical regression inappropriate
Circle of life of scientific modelling

- **Input**
  - Rainfall
  - Topography
  - Sensor measurement at beginning

- **Model**
  - 1D flow model
  - Queuing

- **Calibration**

- **Validation**
  - Height of river at measurement device

- **Output**
  - River height at any location

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Rainfall and topography

Measurement data of river
Model - Framework

- Flow model (river only):
  - 1D advection model
  - 1D shallow water equations

- Rainfall sources:
  - Queuing system of valley runoff
  - Topography-based accumulation

- Parameters:
  - Advection: river speed
  - Shallow water: topography, friction
  - Queuing: queue delay, source factor
Flow model
Advection model

• 1D linear advection equation:

\[ \frac{\partial}{\partial t} h + c \frac{\partial}{\partial x} h = (\text{Prec}) \]

• With advection speed \( c \) and initial condition

\[ h(t=0) = (\text{sensor at } t=0) \]
Shallow water equations

• 1D approximation: Saint-Venant equations (source terms!)
  \[ \partial_t h + \partial_x (uh) = (\text{Prec}) \]

  \[ \partial_t (uh) + \partial_x (hu^2 + g/2 h^2) = -(\text{Top}) - (\text{Fric}) \]

• h water column height, u water speed, g gravity, (Prec)ipitation
  
  (\text{Top}) = -gh\partial b/\partial x, (\text{Fric}) = - ku|u|/h^{1/3}

• We solve using finite difference, with Forward Euler timesteping and Rusanov flux
Results – shallow water – visualization

Downstream wave propagation
Source model and calibration
Queueing

delay [hours]

downstream river location [km]

0 5 10 15 20

0.0 0.5 1.0 1.5 2.0 2.5

time: 51.52 hours

0 5 10 15 20

0.0 0.1 0.2 0.3 0.4 0.5

time: 51.52 hours

water level [m]

downstream river location [km]

0.0 0.2 0.4 0.6 0.7

0.00 0.08 0.16 0.24 0.32 0.40 0.48 0.56 0.64
accumulated precipitation [mm]
Scenarios

• Precipitation:
  • Single, separated peak
  • Low initial flow
  • 120 hours (5days) period
  • 10 minutes interval data

• Season’s difference:
  • Winter
  • Summer
Solver output

- Precipitation

- Water level at sensor location
Validation and calibration

- **Optimization:**
  - Genetic algorithm

- **Parameters:**
  - Delay in queuing
  - Runoff contributing to river flow
  - River flow speed

- **Objective function:**
  - L2 norm between two lines
  - L1 norm between two lines
  - Peak (time and height)
Prediction

• Model calibration (2 hours computer time)
  • Calibrated parameters
  • Rainfall history

• Prediction process (3 minutes computer time)
  1. Getting rainfall forecast (2 hours)
  2. Feed the model
  3. Retrieve predicted wave front (+height)
  4. Issue warning
Simulation results with real data
Results – advection – system behavior
Results – advection – wave visualization

Downstream wave propagation
Improvements

• Queueing model
  • Sub-catchments instead of shortest distance
  • Hydraulic models

• River model
  • Branching of 1D model

• 2D flow equations
  • No source modelling
  • But probably more expensive and too slow

• Second order methods
  • Reduction of numerical dissipation

• Use of existing software packages
  • Basement (VAW), Clawpack...
End

- 3 bananas
- 5 hours spent on Youtube
- 15 croissants
- 20 “classy” menus at Hexagon
- 24 cups of coffee
- 30 source files
- 34 datafiles
- >500 investigated plots
- 1587 code lines
- >10’000 generated movie frames
- >20’000 simulations for optimization