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Predictive Modeling of Urban Flooding Using Finite Differences and Numerical Integration

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INTRODUCTION & AIM

Urban flooding caused by intense rainfall and drainage limitations represents a major environmental and urban risk. This work applies mathematical modeling using derivatives, integrals, and numerical methods to predict water accumulation over time and identify critical flood-risk conditions before safety thresholds are exceeded.

METHOD

1. Continuous Modeling

The continuous accumulation model is defined as:

$$A(t) = \int [R(t) - D(t)]dt$$

The instantaneous rate of water accumulation is:

$$\frac{dA(t)}{dt} = R(t) - D(t)$$

Positive derivative values indicate increasing accumulation and higher flood risk.

where:

- $A(t)$ water accumulation (mm)
- $D(t)$ drainage capacity (mm/h)
- $R(t)$ rainfall intensity (mm/h)

2. Discrete Numerical Modeling

Using explicit forward finite differences:

$$A(t + \Delta t) = A(t) + [R_i - D_i]\Delta t$$

3. Extreme Scenario Analysis

The model incorporates asymptotic behavior and saturation analysis for extreme rainfall scenarios.

$$\lim_{t \to +\infty} D(t) = D_{max} \quad \text{and} \quad \lim_{t \to +\infty} A(t) = +\infty$$

Representing drainage saturation and uncontrolled water accumulation under extreme rainfall conditions.

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RESULTS & DISCUSSION

Identifies accelerated flood-risk conditions

Positive derivative values indicate increasing accumulation and elevated risk.

Predicts critical flood-risk conditions in advance

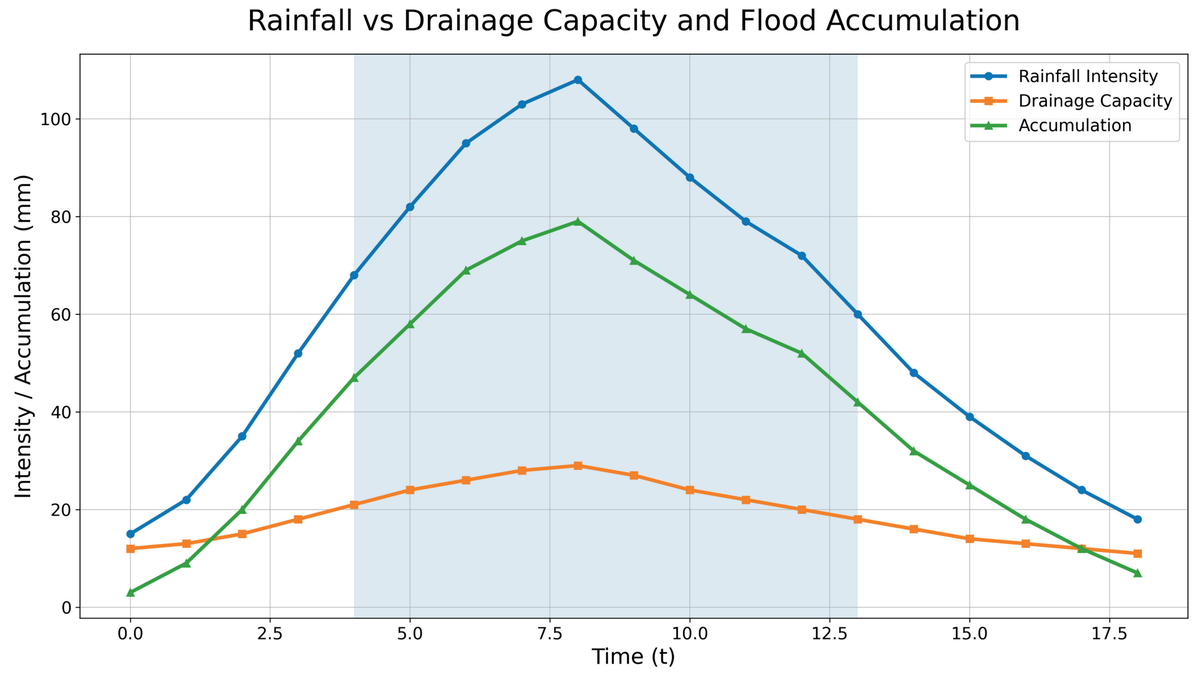
The model detects critical conditions in advance, enabling preventive actions.

Simulates extreme rainfall scenarios

High-intensity events result in rapid accumulation due to drainage limitations.

Enables real-time accumulation monitoring using finite differences

The system tracks accumulation dynamics over discrete time intervals.



CONCLUSION

FloodRadar demonstrates how Calculus I concepts, numerical integration, and finite differences can be integrated into an interactive computational framework for flood-risk visualization and accumulation analysis. The project highlights the practical application of mathematical modeling in environmental monitoring and hydrological simulation.

FUTURE WORK / REFERENCES

Future Work

A future project will explore rocket trajectory optimization and orbital mechanics using numerical simulation techniques.

References

- Access the references and the source code