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Automatic design of flood-resilient urban layouts

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Urban planning is central to flood risk prevention. Flood-sensitive urban planning pursues two goals: reducing flood exposure and vulnerability [1]; but also addressing the influence of urban characteristics on flood flow severity (flow depths and velocities) [2]. Focusing on the latter, we present here a unique software which automatically optimizes the geometry of urban layouts to enhance flood resilience [3]. The optimized parameters describe the arrangement of the road network, the blocks, the parcels, and the buildings. The proposed approach is particularly innovative since, so far, such automatic urban design tools were developed only for totally different objectives (e.g. optimizing sun exposure or distance to parks); but not in the context of flood risk management.

Our automatic urban design system consists of three components: (i) a procedural urban model, (ii) a surrogate for a hydraulic model and (iii) an optimization engine.

- Starting from a set of input parameters p_i (typical road length, width, curvature . . .) the procedural urban model generates urban layouts which mimic fairly realistically real-world urban patterns [3].
- To achieve interactive feedback (i.e. getting the results within a few seconds), the system uses a neural network (NN) to approximate the relationship between urban layout and flood flow characteristics. The NN was trained using a relatively fast 2D porosity-based hydraulic model [4], which in turn was calibrated against a detailed shallow-water model [2].
- A Markov Chain Monte Carlo optimization is used to adjust iteratively the procedural model parameters p_i so as to yield the desired urban layout.

The system was tested for optimizing the layout of an urban district of 1 km by 1 km subject to river flooding. The system runs about one minute to find the optimal urban layout. The system tends to improve the flow conveyance through the urban area by increasing the voids in-between the buildings (e.g., increase road width) and by promoting a more "fragmented" urban pattern (e.g., decrease road length). The optimization reduces the flood water depths in the district by up to 20 to 25%.

Several real-world examples showcase the operationality of the system for improving flood resilience through flood-sensitive urban design [3]. In practice, such an interactive digital tool can valuably assist urban planners and architects to assess the implications of various design decisions on flooding and end up with improved flood-sensitive urban layouts. The approach should be further developed to accommodate more diverse flooding scenarios (e.g. pluvial floods, coastal floods, etc.).

References

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