Title: Bounding Box and Leakiness Ratio Analysis for 3D Leaky Dam Point Clouds: Interactive Monitoring for Maintenance Schedules

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Description: This MATLAB-based workflow provides an integrated two-stage method for quantifying leakiness ratios, structural displacement, and debris accumulation (blockage) in leaky dam structures using photogrammetric 3D point cloud data. The process is designed to facilitate advanced monitoring, performance evaluation, and maintenance scheduling of leaky dams within Natural Flood Management (NFM) catchments.

In Stage 1, the interactiveBoundingBox() function allows users to manually define, adjust, and export a 3D bounding box around a leaky dam point cloud (imported from a .obj file). The bounding box serves as a consistent spatial reference for subsequent analyses. Parameters including box position (x, y, z), dimensions (dx, dy, dz), and rotation (rx, ry, rz) are interactively modified via a user interface and saved in a bounding_box_params.mat file for downstream use.

In Stage 2, the corresponding analysis script loads the bounding box parameters and the same dam point cloud to calculate the blockage ratio—the proportion of points lying within the defined spatial limits, representing the fraction of the dam's cross-section effectively obstructed by material. The leakiness ratio (1−blockage ratio) is also calculated, representing the proportion of open space that allows water to pass through the structure. This simple metric provides a direct, geometry-based quantification of flow permeability through leaky dams and enables consistent comparison across designs and configurations.

This approach aligns with methods described in recent NFM literature, which assess the relative area of a barrier that remains open to flow. Here, 3D scans of dams are first generated using photogrammetry software (e.g., Scaniverse). The identical-sized bounding box defined in Stage 1 standardises cross-sectional comparisons across dam types and sites. By projecting enclosed points onto a 2D plane representing the upstream-facing dam surface, the workflow allows users to infer the degree of in-channel storage and structural porosity.

The analysis can be extended across multiple temporal datasets (e.g., baseline, 6 months, 12 months) to track changes in leakiness ratio and centroid displacement through time. These metrics are used to evaluate debris build-up, detect potential dam movement or failure risk, and generate maintenance recommendations based on defined blockage growth thresholds (e.g., > 30 % debris increase).

Visual outputs include 3D point cloud visualisations highlighting blocked and open areas, time-series plots of blockage and leakiness ratios, and centroid drift diagrams for assessing structural stability. Together, these tools provide a reproducible, quantitative framework for assessing leaky dam structure and performance, structural integrity, and hydrological effectiveness through time using repeat 3D photogrammetry surveys that can be undertaken on a smartphone.

Requirements: MATLAB R2023a (or later).
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User Manual

1. Overview

This MATLAB workflow provides tools to quantify the blockage ratio, leakiness ratio, and structural displacement of leaky dams from 3D point cloud data obtained via photogrammetry.

It consists of two primary stages:

Stage 1 – Bounding Box Definition: Interactively create and export a 3D bounding box around a dam point cloud.

Stage 2 – Blockage and Leakiness Analysis: Calculate blockage and leakiness ratios within the bounding box, and (optionally) analyse multiple time-step datasets to assess debris accumulation and structural movement.

2. Input Requirements

Photogrammetric 3D point cloud exported as an .obj file.

Example: LeakyDam1_T0.obj

MATLAB R2023a or newer (with Computer Vision Toolbox for pointCloud functions).

Stage 2 requires the file bounding_box_params.mat, generated automatically during Stage 1.

3. Workflow Summary

Stage 1 - Build Bounding Box Around Dam With Interactive Box

1. Stage1_InteractiveBoundingBox ()
   Open MATLAB and ensure your .obj file (e.g., UseYourOBJFile.obj) is in the working directory.
2. Run: interactiveBoundingBox
3. Adjust the bounding box interactively using the sliders for:
   - Position: x, y, z
   - Size: dx, dy, dz
   - Rotation: rx, ry, rz
4. Click "Export Box Params" to save configuration data as bounding_box_params.mat.
   This file contains the box dimensions, centre, rotation matrices, and corner coordinates.

Stage 2 – Blockage, Leakiness, and Maintenance Analysis

1. Place the bounding_box_params.mat file and your .obj file(s) in the same folder.
2. Edit the variable objFile at the top of the script to match your file name.
3. Run the script section by section (or the whole file).
   The script will:
   - Compute the blockage ratio (fraction of points within the box).
   - Compute the leakiness ratio, L_r = 1 – blockage ratio
   - Display both metrics in the Command Window.
   - Visualize the dam, highlighting blocked points in red.
4. (Optional) For multiple time steps, define filenames in:
   ```
   pcFiles = {"T0.obj", "T6.obj", "T12.obj"};
   ```
   The script will then:
   - Track changes in blockage and leakiness over time.
   - Compute centroid drift to assess structural movement.
   - Recommend debris clearance if blockage growth exceeds the set threshold (default: 30%).

5. Two plots are automatically produced:
    - Left panel: Blockage vs Leakiness over time.
    - Right panel: Centroid drift (structural stability).

4. Output Files and Visualisations

Output File	**Description**
bounding_box_params.mat	Bounding box position, size, rotation, and corner coordinates
Command Window output	Displays blockage, leakiness, debris accumulation, and stability metrics
MATLAB figures	3D scatter plot (Stage 2) and time-series plots (Stage 3).

5. Notes and Recommendations

- Ensure all .obj point clouds are aligned to the same coordinate system before analysis.
- For consistency across dams, use the same bounding box dimensions when comparing designs (engineered, natural, or control).
- The leakiness ratio provides a simple yet effective indicator of flow permeability and complements more detailed hydrodynamic modelling.
- Thresholds for maintenance alerts can be adjusted at: threshold = 0.30;
- For long-term monitoring, repeat 3D scans after major flow events or debris build-up.

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