Image processing for studying size segregation in bedload transport: detection and tracking
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1. Context and objectives

**Global aim:** studying bedload transport thanks to experiments with two-size beads in a water flow.

**Main objective:** track beads over long time sequences to better understand size segregation responsible for complex morphology structures.

The idea: propose an [online particle filter-based tracking algorithm](#) (framework from [2])
1. Include adapted multiple motion models with known mechanical dynamics to anticipate bead locations.
2. Introduce an observation model from a conditional likelihood to handle detection errors.

2a. Experimental setup

2b. Tracking & bedload transport

*Example of 2 trajectories from the experiment*

Tracking bedload sediment transport to study:
- Velocities, concentrations, bedload granular rheology
- Size segregation and associated morphology


**Stage 1: Object detector**
- Use specific morphological operations (erosion, hconvex, cross-correlation, etc.)
- Measure motion states based on neighborhood and velocities
- Return observation state \( s_t = \{x_t^{(i)}, w_t^{(i)}, \theta_t^{(i)}\} \)

**Stage 2: Data association**
- Perform greedy algorithm on best matching combinations

**Stage 3: Particle filtering**

*Objective:* Estimate state \( \mathbf{c}_t = \{x_t, u_t, y_t\} \) of targets according to observations \( z_t \)
1 target \( \rightarrow \) cloud of \( N \) particles, 1 particle \( \rightarrow \) 1 state \( \mathbf{c}_t^{(i)} = \{x_t^{(i)}, w_t^{(i)}, \theta_t^{(i)}\} \)

Based on a Sequential Monte Carlo approach (SMC) and a Markov Chain:
1. Prediction: predict target state according to evolution model on particles
   - 3 motion models based on bedload dynamics:
     - Resting - not moving: \( (x_{t+1}, y_{t+1}) = (x_t, y_t) \)
     - Rolling - sliding on others: \( (x_{t+1}, y_{t+1}) = (x_t, y_t + \Delta y) \) \( \Delta y \sim N(0, \sigma_y) \)
   - Saltating - bouncing on others: \( (x_{t+1}, y_{t+1}) = (x_t + \Delta x, y_t) \) \( \Delta x \sim N(0, \sigma_x) \)

2. Correction: correct predicted state thanks to observations
   - Particle importance weighting
   - Normalize weights and resample particles

3. Final target state estimation by averaging resampled particles

4. Example of tracking results

5. Conclusions & Perspectives

- New online particle filter-based tracking algorithm based on multiple dynamic models:
  - Input of object mechanical dynamics helps approaching real trajectories.
  - Allows studying bedload transport with high confidence.

**Perspectives:** apply to long sequences of sediment transport to study high and lower frequency phenomena

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**References**

