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EP41C-2325: Computer Vision Tool for Lobe-and-Cleft Structures Tracking in Gravity Currents Image Data

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Objectives

This work aims to provide an image processing tool that:

- Achieve an enhanced analysis of gravity current image data, where clefts and lobes are characteristic structures at the leading edge of these flows, associated with depressional features on the deposition map after particle settling.
- Perform automatic tracking of clefts along the currents, enabling measurements of the mean lobe size as a length characteristic of the flow.
- Overlay the cleft tracks onto the deposition map, enabling the user to establish a correlation between the tracks and features on the map.
- Can be employed to analyze the link between the deposition map and the turbulent flow that produced it.

Flow Configuration

- High-order solver of the incompressible Navier-Stokes equations simplified by the Boussinesq approximation `Xcompact3d` [1, 2], designed for supercomputers.

$$\frac{\partial u_j}{\partial x_j} = 0, \tag{1a}$$

$$\frac{\partial u_i}{\partial t} + u_j\frac{\partial u_i}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{1}{Re}\frac{\partial^2 u_i}{\partial x_j \partial x_j} - Ri\delta_{i2}\varphi, \tag{1b}$$

$$\frac{\partial \varphi}{\partial t} + (u_j - u_s\delta_{2j})\frac{\partial \varphi}{\partial x_j} = \frac{1}{ReSc}\frac{\partial^2 \varphi}{\partial x_j \partial x_j} \tag{1c}$$

being u_i the velocity field, p the pressure, φ the scalar concentration, δ the Kronecker delta, u_s the settling velocity, $Re = 8{,}950$, $Sc = 1$ and $Ri = 1$.

- LES modelling using Implicit Spectral Vanishing Viscosity (ISVV) [3].
- The computational set-up is based on the lock-release configuration [4]:

Computer Vision

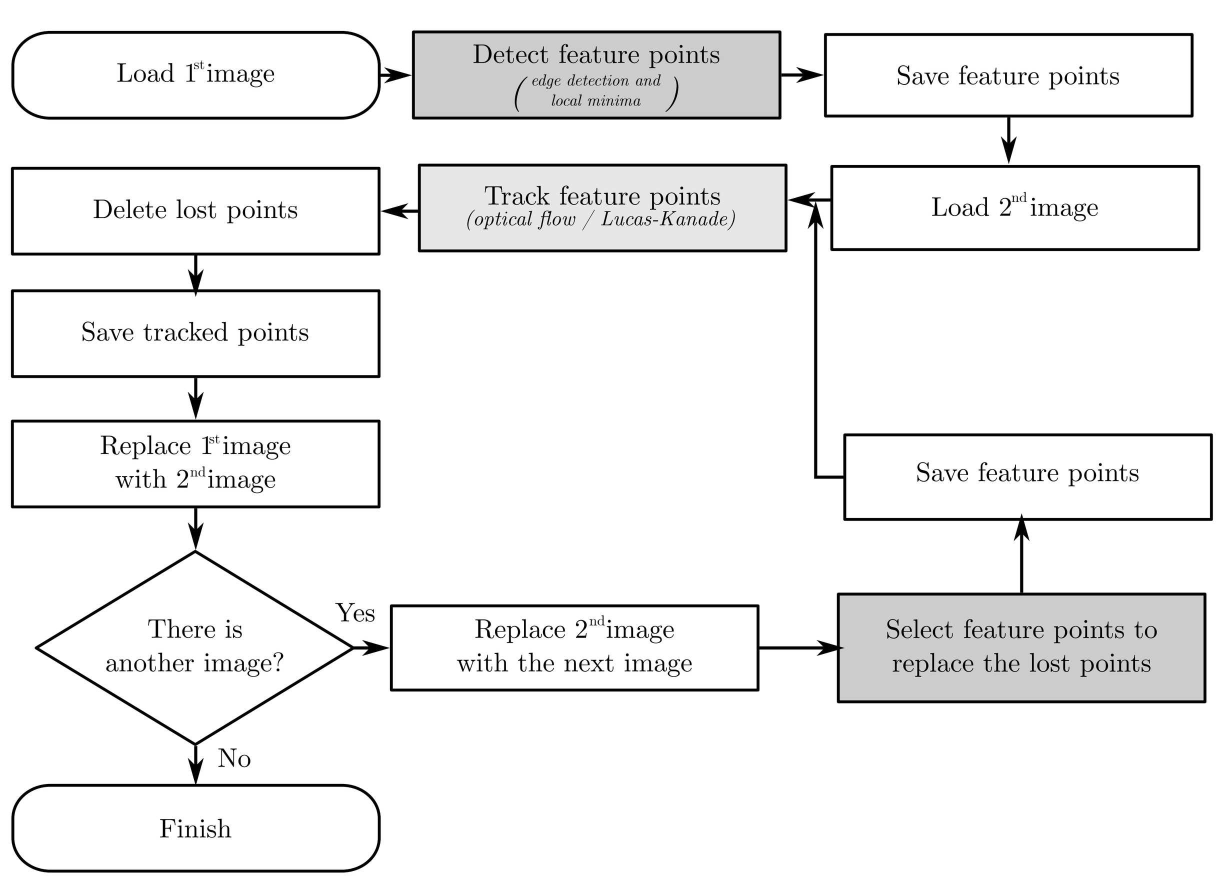

Figure 1:The detection and tracking of features is done according to this flow chart. Which is a modified version of the KLT method [5]. However, instead of detecting clefts using corner detection, it runs a local minima scan at the gravity current leading edge in the spanwise direction.

Results

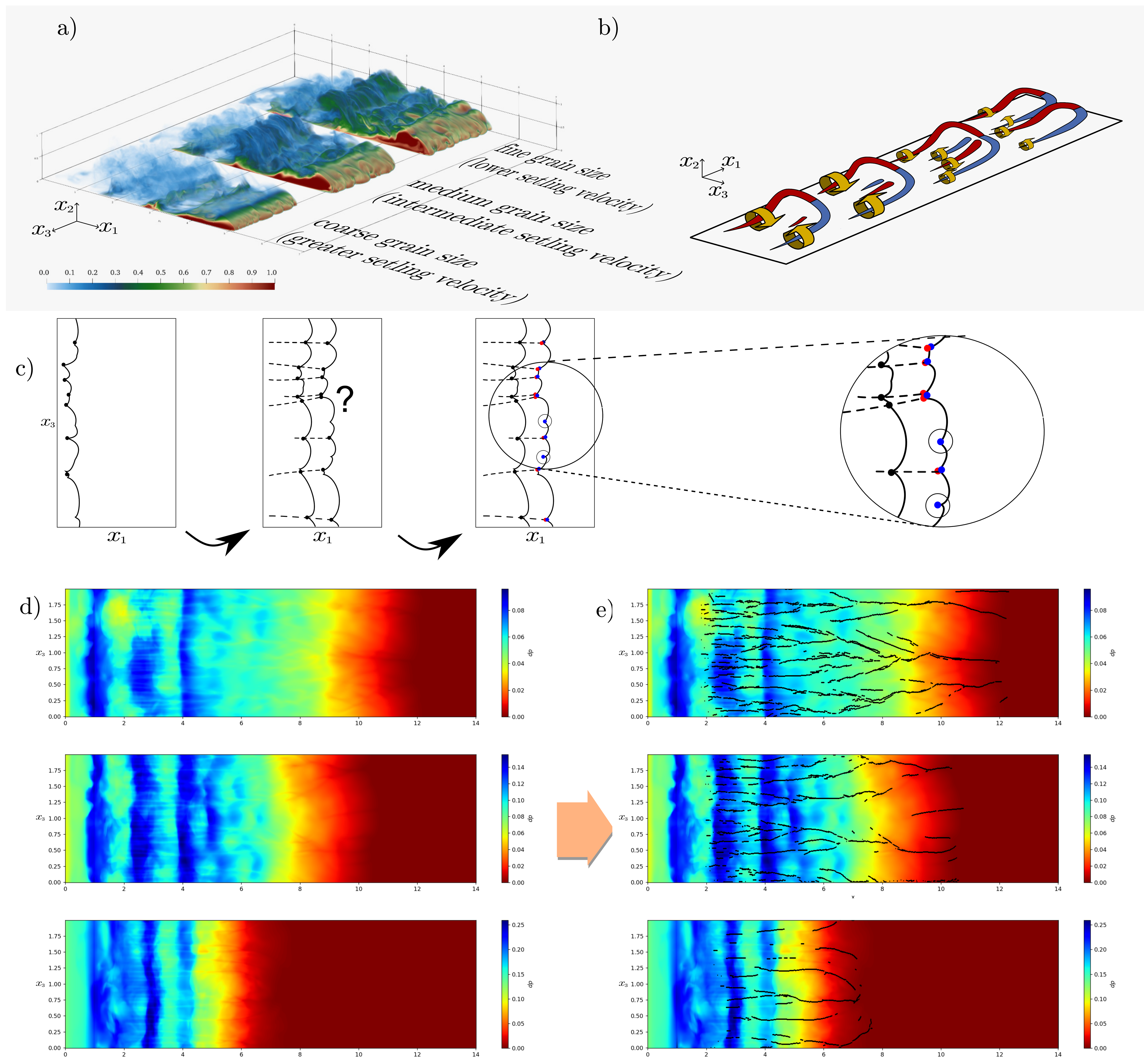

Figure 2:(a) Were conducted three simulations of mono-disperse particle-laden gravity currents. For each simulation were used different settling velocities for the particles, to simulate different grain sizes.The temporal evolution, represented by the concentration field. The spanwise extension length is $L_3 = 2$, the streamwise length $L_1 = 14$ and the height $L_2 = 1$. The computational domain is discretized in $1945 \times 240 \times 121$ mesh nodes, and a time step of 5×10^{-4} is used for a total of 7×10^4 iterations. Other authors have associated the cleft tracks with the deposit topology. In their study, [6] conducted a manual comparison between the path of clefts and the deposit signature on the bottom of the flow in a channel lock release configuration. The findings of their research provide compelling evidence of a correlation between impressions at the bottom of the flow and the trajectory of the cleft. (b) They attributed this behavior to turbulent structures within the current. (c) To implement a feature tracker using a combination of local minima detection and optical flow requires an iterative algorithm where new features should be discovered, and certain features should be declared lost. The [5] algorithm combines local minima detection with an interactive form of the Lucas-Kanade optical flow. Applying this algorithm to a video containing gravity currents, moving fronts should automatically trace the path of the clefts. In (d) is plotted the deposit map, where the color represents the deposit height. (e) We can that the track lines are located right in the various dressional zones over the deposit.

Summary and Conclusions

Turbulence-resolved numerical simulations of mono-disperse particle-laden gravity currents produce a considerable volume of data with high spatio-temporal resolution. This work showed the use of computer vision techniques to analyze spatio-temporal features in gravity current flows. The technique employed in the prototype developed in this work, is a modified KLT method [5], which uses local minima to identify clefts and an optical flow algorithm [7] to track the detected clefts, both appropriately integrated to discard lost corners when comparing two frames. Quantitative results associated with the method were presented previously verified [5], and the correlation between the deposit imprint and the paths of the clefts can be qualitatively assessed with the findings of the present study.

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https://youtu.be/ZX4qjTJBsao
Particle-laden gravity current propagation, video available on YouTube.