OpenCV hardware acceleration with vAccel

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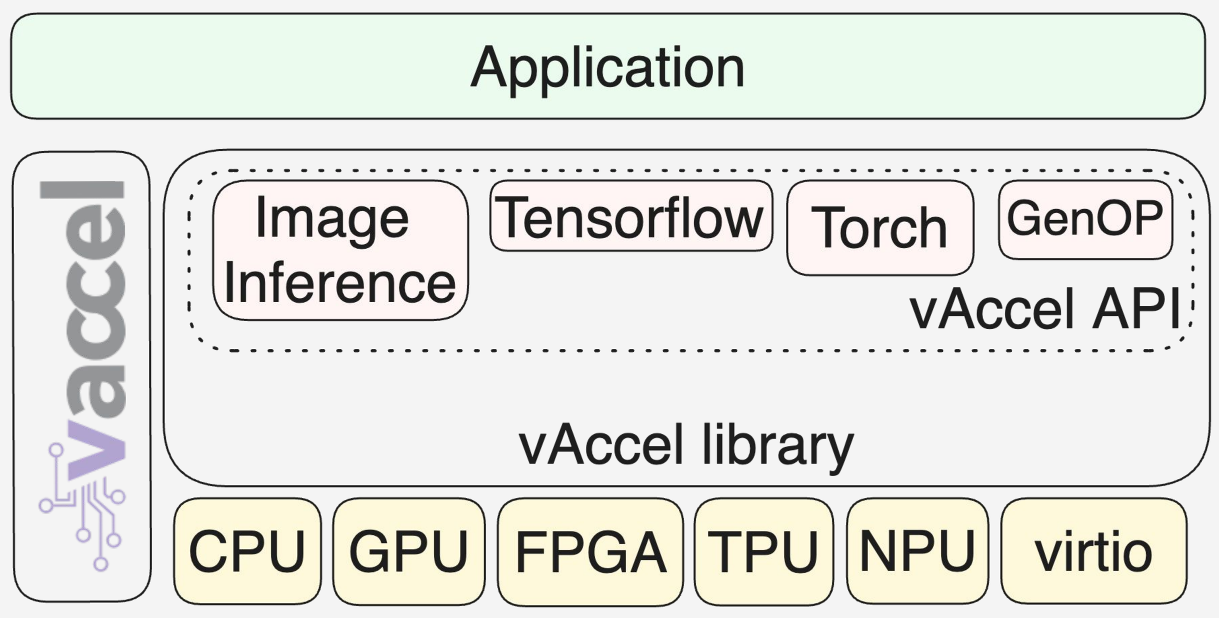
Motivation

Deployments in multi-tenant Cloud/Edge infra suffer from poor isolation ➜ sandbox user code in microVMs

- ➜ Limited support for accelerator drivers
  - ➜ Hardware partitioning – Porting of a device driver
  - ➜ Paravirtualization – Porting of a virtual device driver
  - ➜ Remote API – Porting of the framework
- ➜ Limited support for acceleration frameworks
  - ➜ Huge code base
  - ➜ Diverse dependencies
  - ➜ Bound to a language

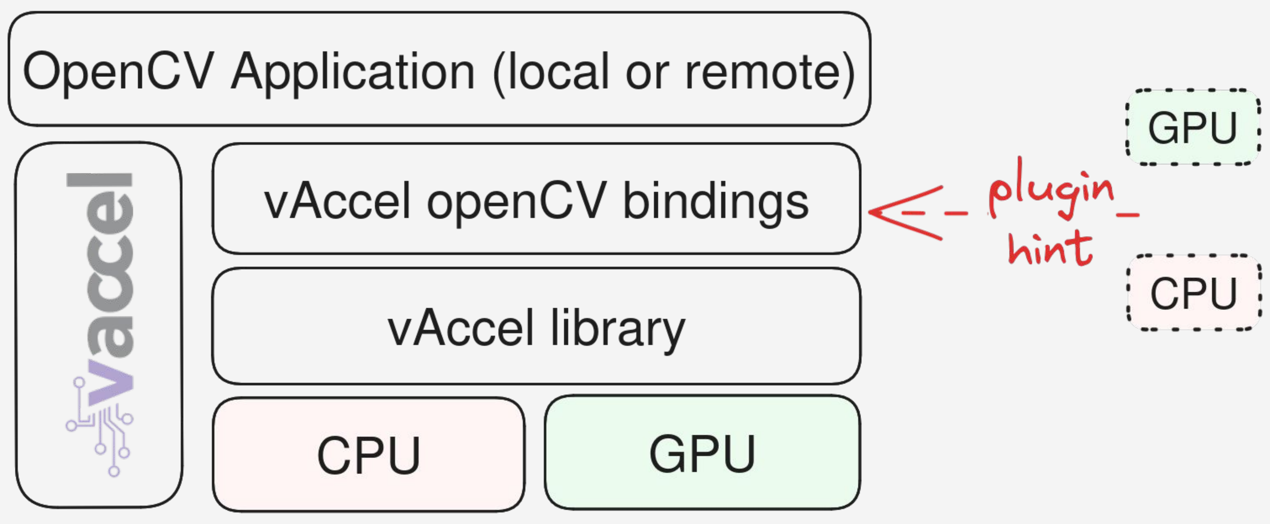
vAccel

- ➜ vAccel decouples the function call from its hardware-specific implementation
- ➜ Features:
  - ➜ **Hardware-agnostic** API
  - ➜ Acceleration in **function** granularity
  - ➜ **Portability** and **interoperability**



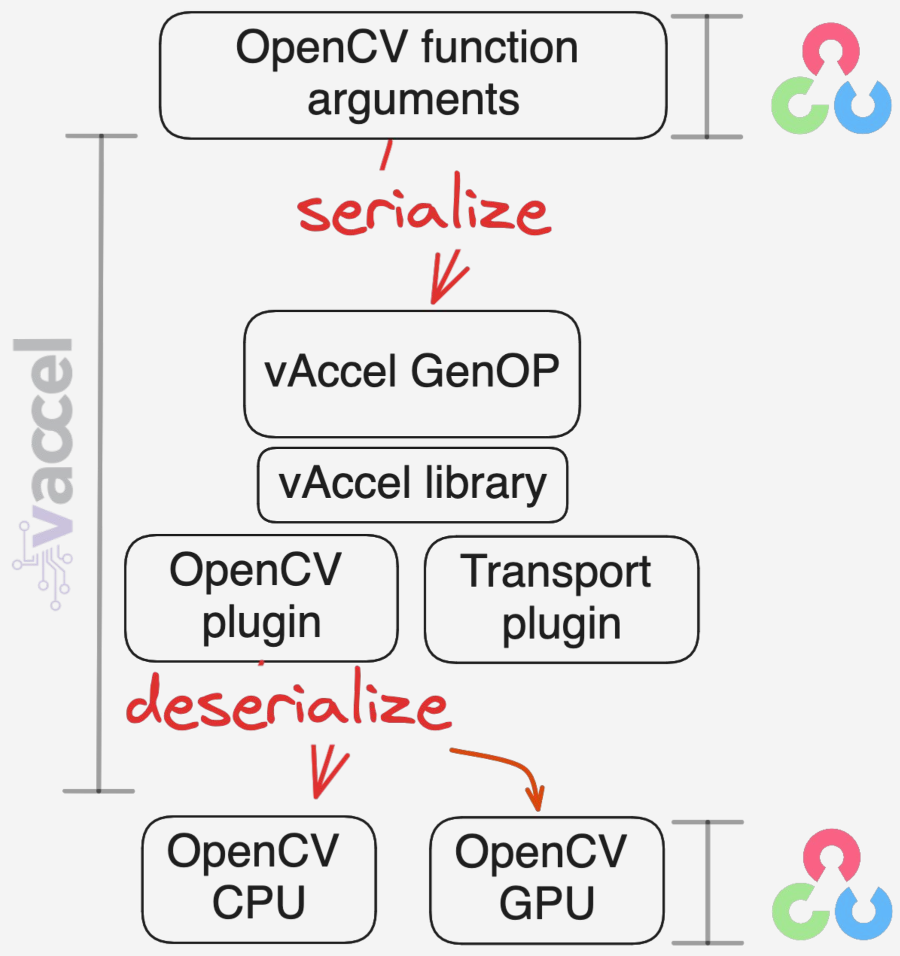
Plugin change at Runtime

- ➜ Introduce a mechanism for vAccel to change the backing plugin at runtime
  - ➜ Requirements Bitmap
  - ➜ Plugin features Bitmap



OpenCV Bindings

- ➜ Agnostic to the user
  - ➜ Overload original OpenCV function (e.g. `calcOpticalFlowPyrLK()`)
  - ➜ Parse arguments & **serialize** them
  - ➜ Issue the vAccel OpenCV operation (equivalent to vAccel `GenOP`)
  - ➜ Go through the relevant plugin (virtio / Transport or local)
  - ➜ In the plugin, **deserialize** the arguments
  - ➜ Call the respective OpenCV operation

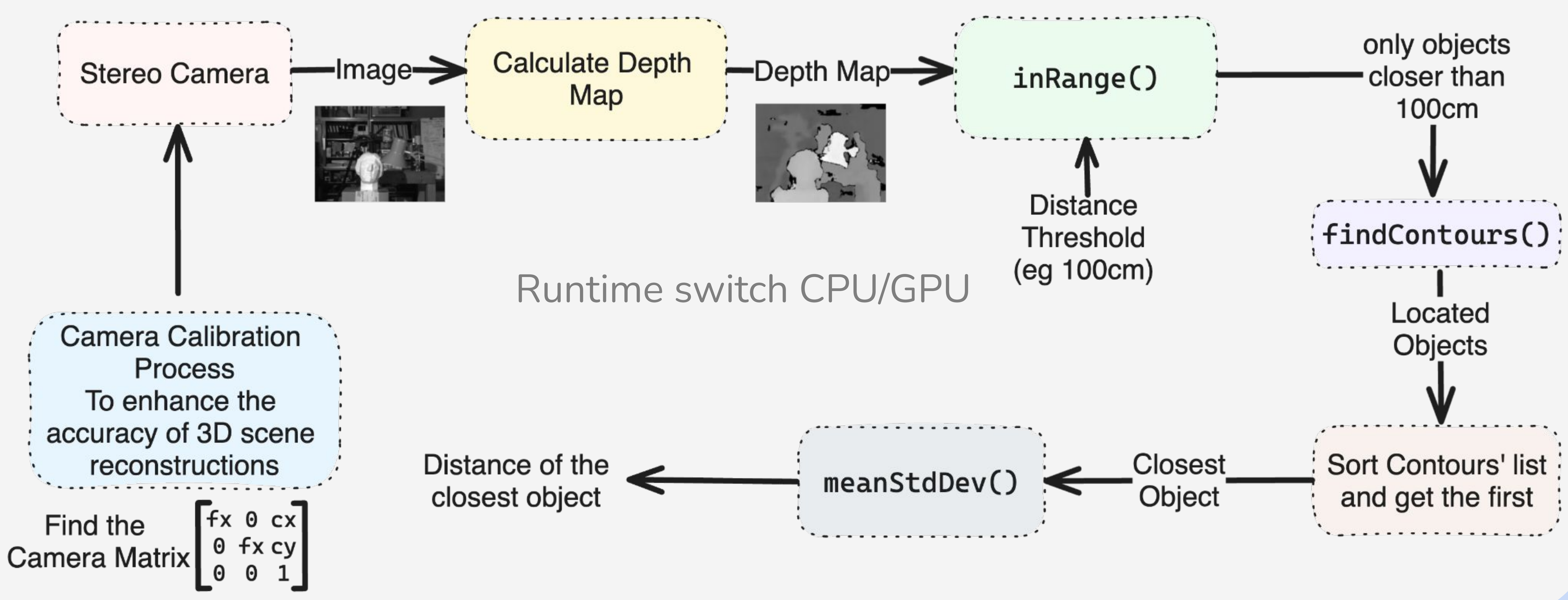


Obstacle Avoidance

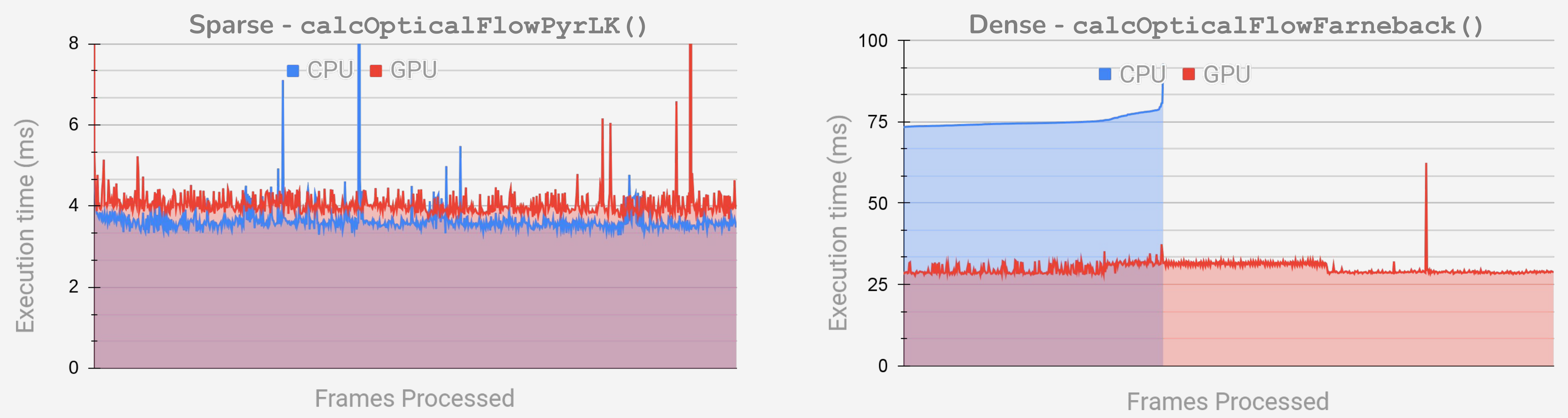
- ➜ Stereo Calibration and Rectification
- ➜ Disparity Map and Depth Map
- ➜ Obstacle Avoidance

Criteria:

- ➜ response latency
- ➜ energy consumption
- ➜ execution time



Initial Evaluation - Optical Flow (sparse / dense)



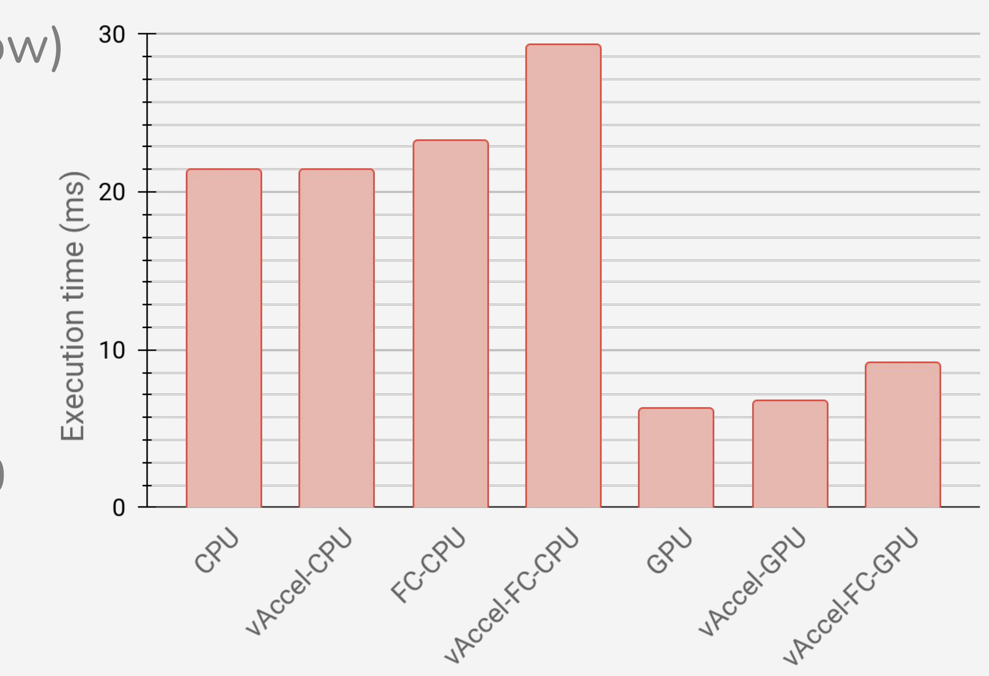
- ➜ 913-Frame video (OpenCV example)
- ➜ Hardware: Jetson AGX Orin
- ➜ generic & sandboxed containers
  - ○ runc
  - ○ AWS firecracker (kata-containers)
- ➜ Sparse behaves marginally better on the CPU
- ➜ Dense cannot cope with the frame rate on the CPU, leading to frame drops.
- ➜ The plugin change is done at runtime

Initial Evaluation - native vs vAccel

Naive example (OptFlow)

Benchmark Spec:

- ➜ Jetson AGX Orin
- ➜ local/VM execution
- ➜ AWS Firecracker
- ➜ CPU/GPU
- ➜ two frames for 1000 iterations (avg)



Challenges & Plan

- ➜ Address argument serialization / deserialization
  - ○ push logic to the transport layer (?)
- ➜ Address copy overheads (serde & transport)
- ➜ Simplify build process (CUDA/GPU support)
- ➜ Provide end-to-end function execution for the Obstacle Avoidance example
- ➜ Finetune CPU/GPU execution of OpenCV functions to optimize:
  - ➜ power
  - ➜ performance
  - ➜ execution time

[1] vAccel: https://docs.vaccel.org
[2] vAccel OpenCV bindings: https://github.com/nubificus/opencv-vaccel
[3] Batuhan Hangün, Önder Eyecioğlu, Performance Comparison Between OpenCV Built in CPU and GPU Functions on Image Processing Operations, 2019, https://doi.org/10.48550/arXiv.1906.08819
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[5] Yuan, J., Jiang, T., He, X. et al. Dynamic obstacle detection method based on U–V disparity and residual optical flow for autonomous driving. Sci Rep 13, 7630 (2023). https://doi.org/10.1038/s41598-023-34777-6
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