A System to Enable Adaptive Sampling of Stream Surface Velocity Using Sensor-Based Optical Flow

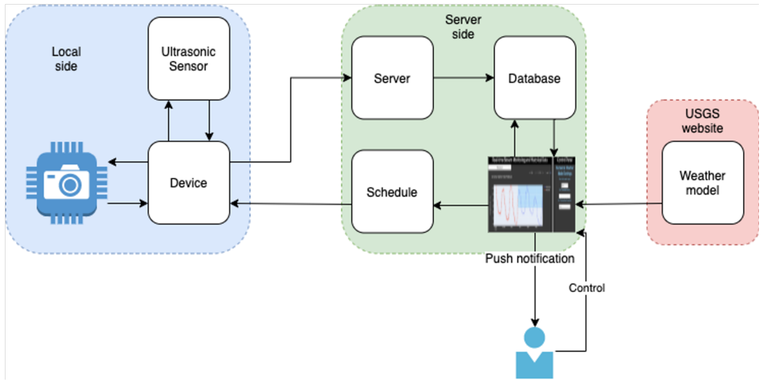
Eve Hu, Juntao Li, Matthew Thomas, Poras Siganporia, Reese Grimsley, Bob Iannucci

Carnegie Mellon University Silicon Valley

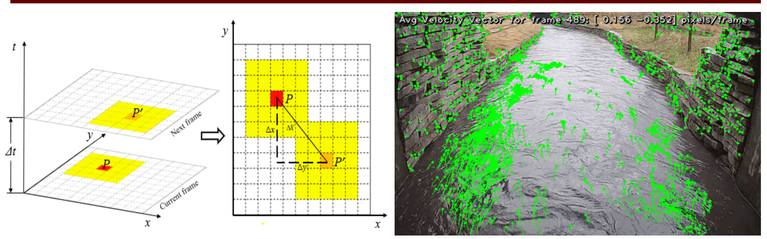
Problem

- Ubiquitous and reliable flooding prediction of streams will require pervasive network of stream sensors that accurately measure stream discharge in real-time.
- Previous platform, EnviSense, has laid the groundwork for measuring and communicating stream stage at low power over LPWAN. We extended the platform for optical flow which required adaptive communication.

Architecture



Optical Flow Algorithm



- Lucas-Kanade Optical Flow Detection Technique.
- Extract features from successive frames and track them.
- **Compute Optimizations:**
  - Use only a sub-section of an entire image frame.
  - Impose upper limit on maximum number of features.
  - Reduce frame capture frequency.

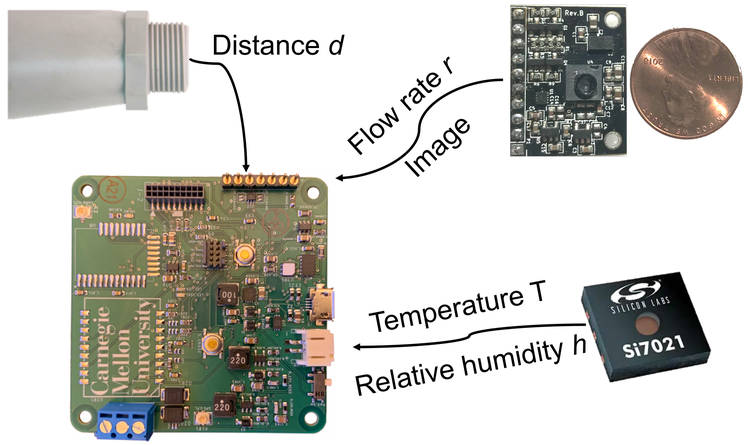
Power Considerations – Optical Flow

- Processing 2 seconds of 20fps video consumes **218uAh per execution**.

Goals

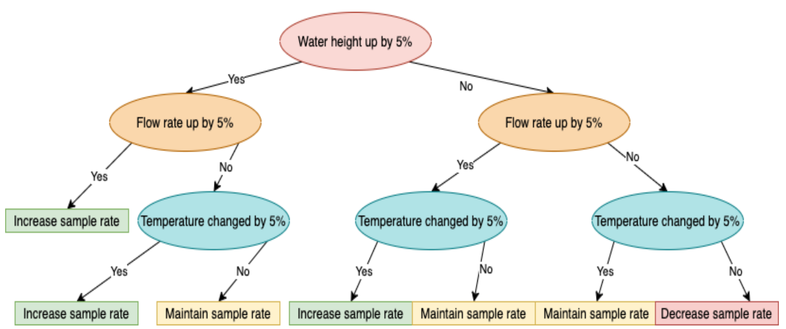
- **Design a system that can measure and communicate stream stage and flow rate with:**
  - **Adaptivity** – System conserves resources by adapting communication/storage of measurements to weather model predictions and on-device sensor fusion.
  - **Low Power** – Current draw <100 µA with few spikes.
  - **On-device Compute** – Write computationally efficient optical flow algorithm to estimate flow rate on device.

EnviSense: Heterogeneous Sensor Data



- ATSAM 3X8E processor core
- GPS, SDI-12, Bluetooth, LoRa capability

Sensor Fusion



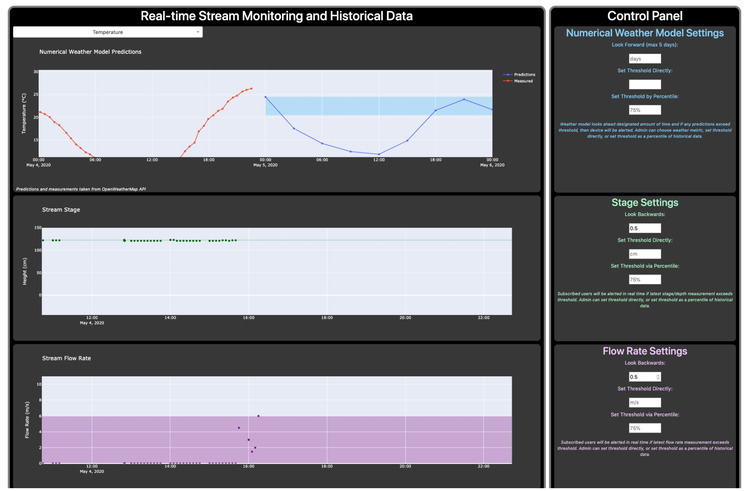
- Device makes adaptation based on local sensor data
- **Results:** increase, decrease or maintain the sample rate

Camera Selection

Tradeoffs: power consumption, price, performance, packaging

	FLIR Lepton IR camera	MLX90640	PMW3901 Optical Motion Tracking
Performance	• 80 x 60 px • 57 x 71 FOV • Refresh rate 8.7Hz • -10~450dB	• 32 x 24 px • 35 x 55 FOV • Refresh rate .5~64Hz • -40~300dB	• 35 x 35 px • 42 x 42 FOV
Power	150mA, standby 5mA	<25mA	9mA
Packaging	Operating temperature: -10~80	Operating temperature: -40~80	Operating temperature: 0~40
Price	$150~200	$54	$23

User Interface



Future Work

- Packaging Camera into hardware enclosure.
- Research feature detection in Thermal IR Imagery.
- Improve Scheduling system (Reese).
- Further optimization and Migration of Optical Flow Algorithm on EnviSense device.