Rapid Prototyping of a Positioning System

Using the OpenHPS Framework

Maxim Van de Wynckel

Web & Information Systems Engineering Lab
Vrije Universiteit Brussel

VRIJE UNIVERSITEIT BRUSSEL

WEB & INFORMATION SYSTEMS ENGINEERING

OpenHPS

Positioning System

OpenHPS

"A positioning system is a mechanism for determining the position of an object in space."

- Wikipedia (2022)

Positioning System

OpenHPS

*"A positioning system is a mechanism for determining the position of an **object** in **space**."*

- Wikipedia (2022)

Object

What are you tracking? A person, an asset or a phone?

Space

Outdoor, indoor, on a table or on a game board?

Use Cases

OpenHPS

- Navigation

Navigate a person from point A to point B

- Tracking

Asset tracking, customer tracking, tracking items on a table

- Location Awareness

Trigger an action whenever a specific person is in a room

- Mapping

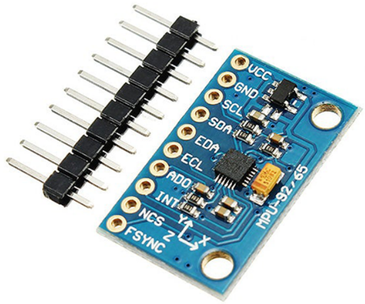
Geospatial mapping of an environment

Technologies

OpenHPS

Technologies used to obtain sensor data for positioning

- Camera (Stereoscopic/Monocular/Omnidirectional)
- Bluetooth beacons
- WLAN access points
- Ultrawideband beacons
- LIDAR
- Inertial measurement unit
- Visible light communication
- ...



Algorithms

OpenHPS

Algorithms used to process sensor data

- Lateration
- Proximity positioning
- Fingerprinting
- Computer vision
- Dead reckoning
- Sensor fusion
- ...

Open Source Solutions

OpenHPS

- AnyPlace *https://anyplace.cs.ucy.ac.cy/*
- FIND *https://github.com/schollz/find3*
- IndoorLocation *https://github.com/IndoorLocation*
- Navigine *https://github.com/Navigine*
- RedPin *http://redpin.org/*
- Traccar *https://github.com/traccar*

What is OpenHPS?

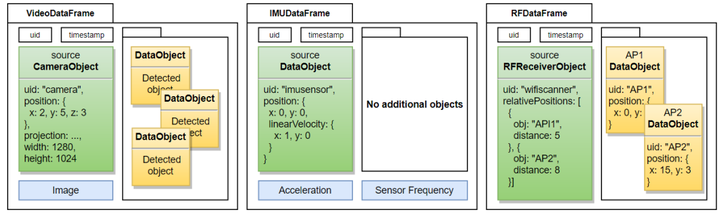
OpenHPS

An Open Source Hybrid Positioning System

Data Frame

Data frames are envelopes that are transmitted and processed through a positioning model. These frames are created by source nodes (e.g. sensors) and contain one or more data objects needed to process the frame.

A frame should contain a single reading of a sensor (such as an image of a video stream or current acceleration) and not permanent or calculated information.



Creating data frames

OpenHPS is a framework that processes sensor information to retrieve a position for one or more data objects. These objects are contained within an envelope called a data frame.

```
import { DataObject, DataFrame } from '@openhps/core';

const myObject = new DataObject("bsigner", "Beat Signer");
const frame = new DataFrame();
frame.addObject(myObject);
```

```
(method) DataFrame.addObject(object: DataObject): void
```

A basic data frame supports the addition of objects. Extended versions of this basic data frame also add additional sensor data.

Creating a custom data frame

Similar to data objects, decorators have to be used to indicate a serializable data frame.

```
import {
    DataFrame,
    SerializableObject,
    SerializableMember
} from '@openhps/core';

@SerializableObject()
export class QRDataFrame extends DataFrame {
    public rawImage: any = undefined;
}
```

What is OpenHPS?

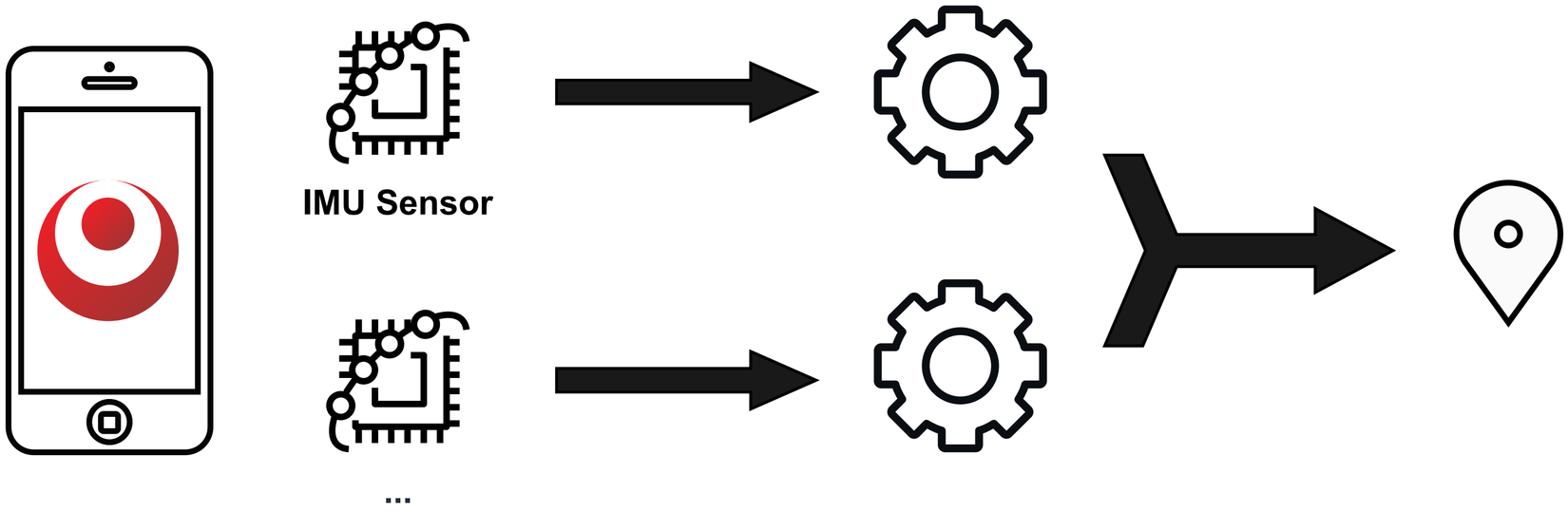
OpenHPS

An Open Source Hybrid Positioning System

- Any technology
- Any algorithm
- Various use cases
- Flexibile processing and output
  - Accuracy over battery consumption, reliability, ...
- Aimed towards developers and researchers

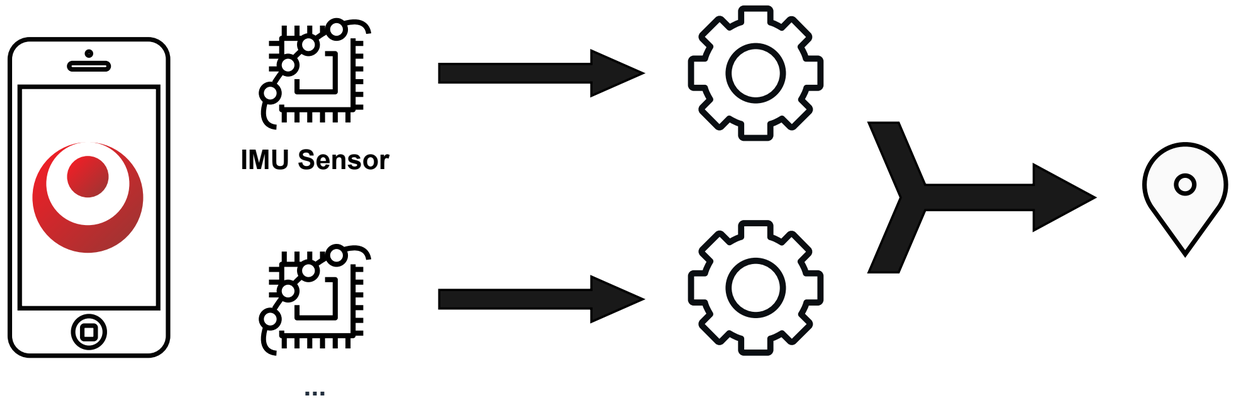
Process Network Design

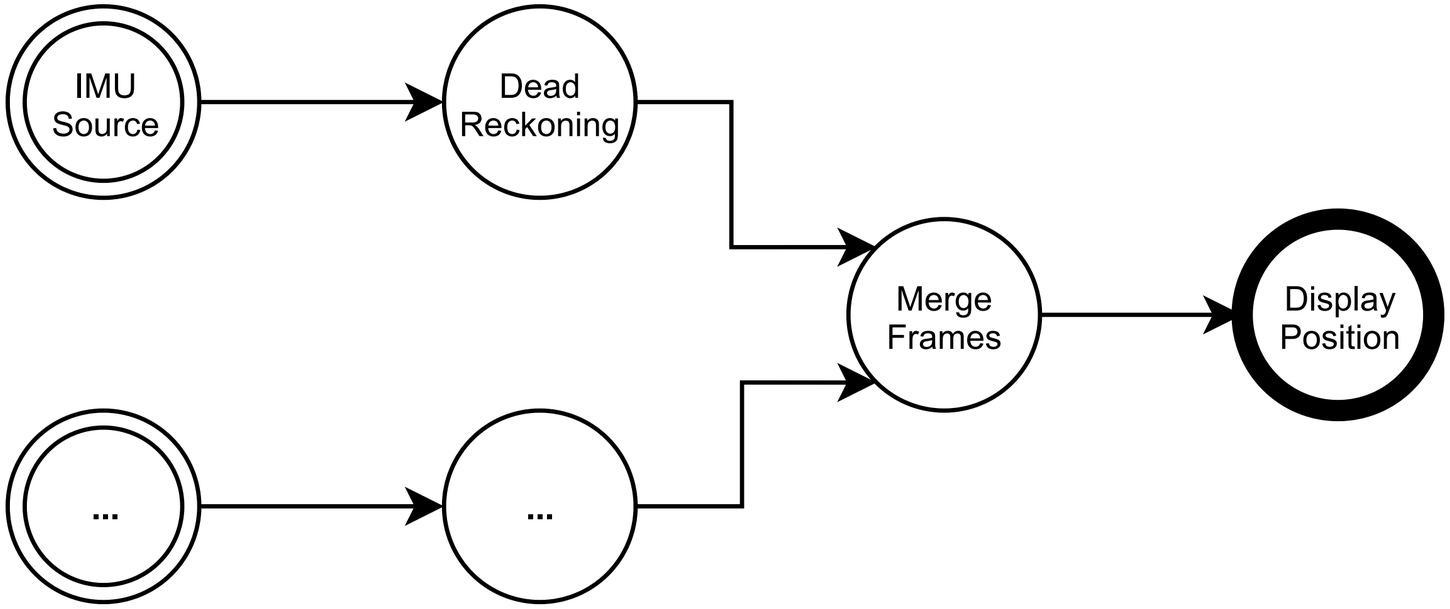
OpenHPS



Process Network Design ...

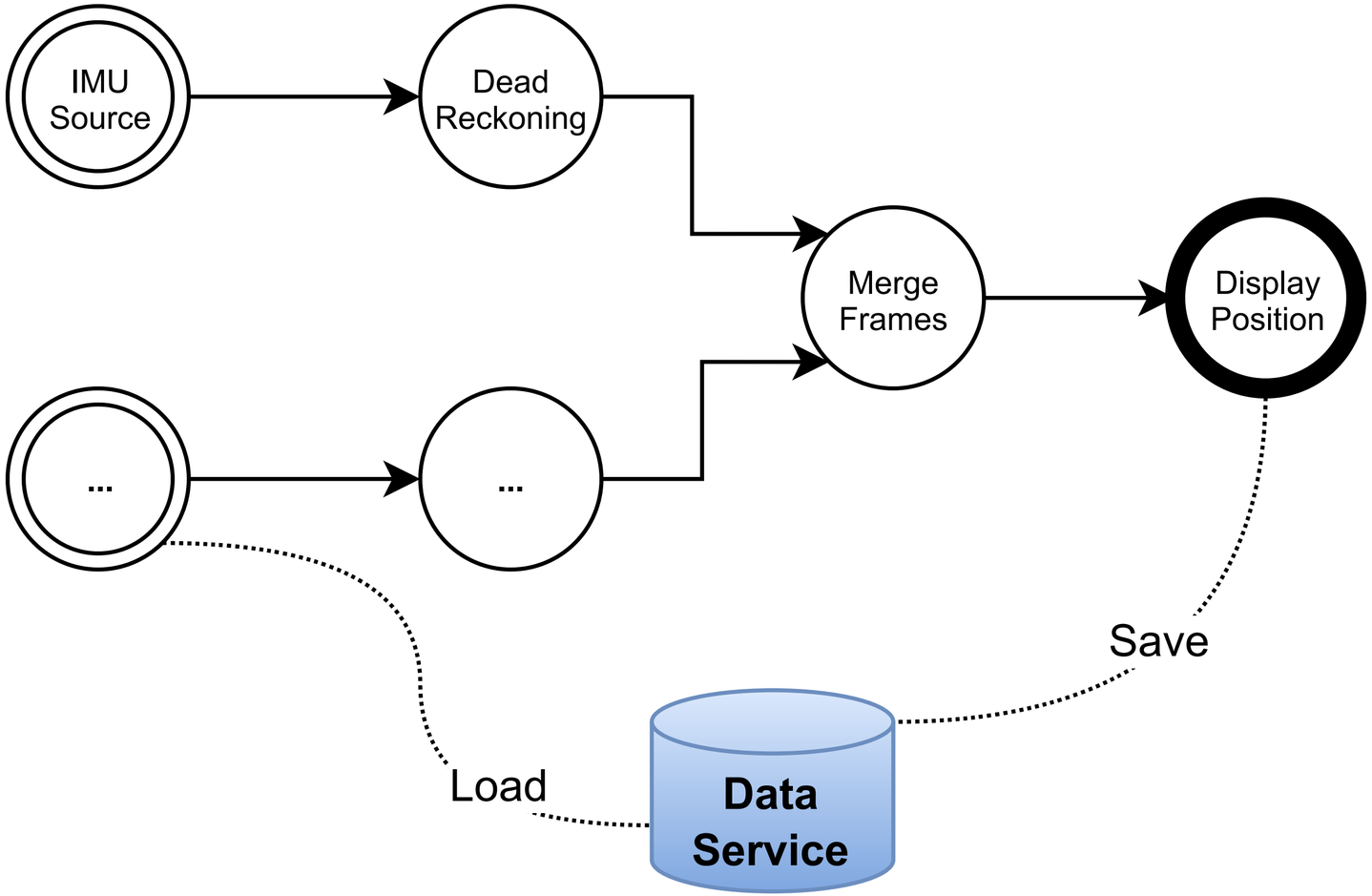
OpenHPS





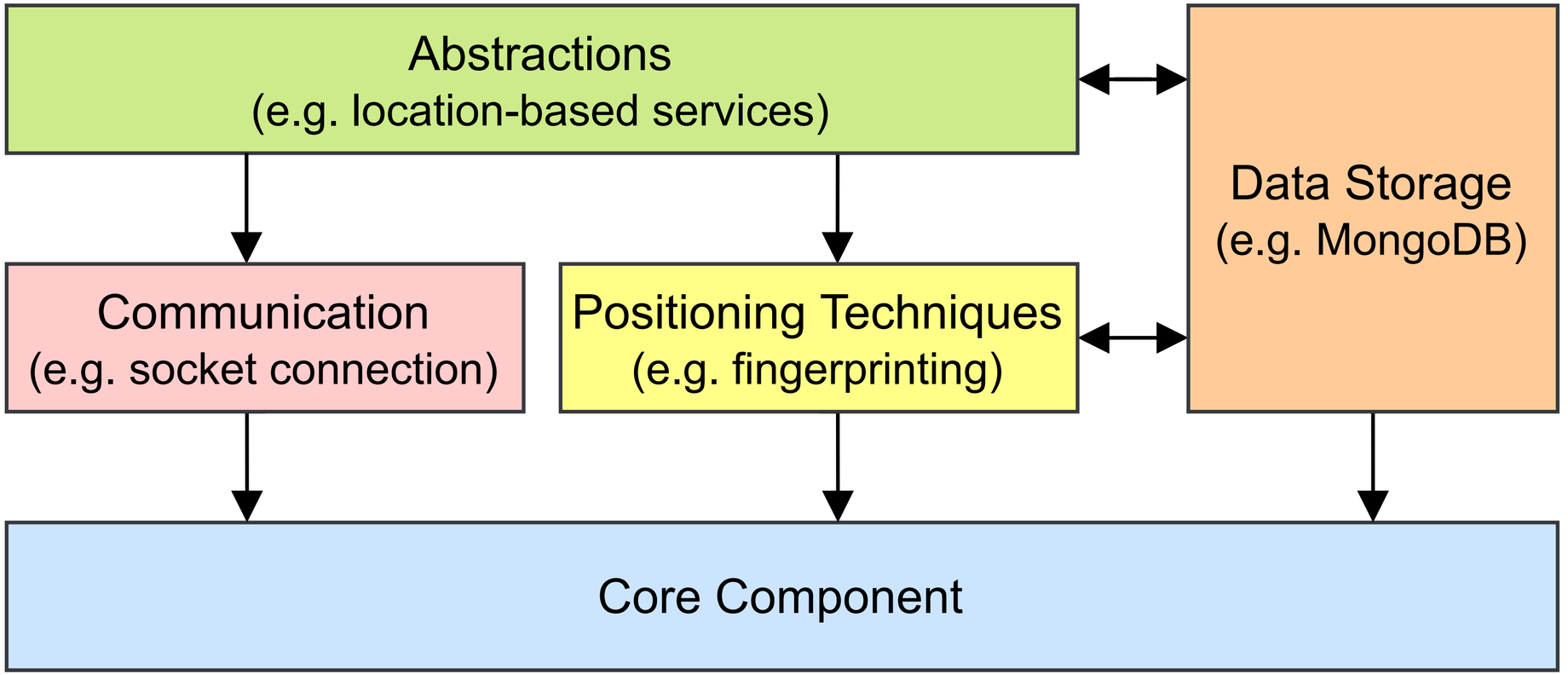
Process Network Design ...

OpenHPS



Modularity

OpenHPS



Current State

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Communication

Socket, MQTT, REST API

Data Storage

MongoDB, LocalStorage, RDF

Positioning Algorithms

IMU, fingerprinting, RF, OpenVSLAM

Abstractions

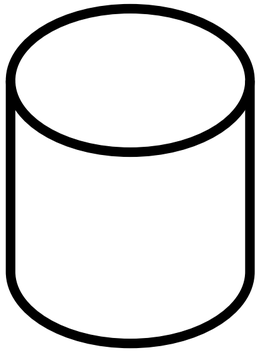
Geospatial, location-based services

Mobile (sensor source)

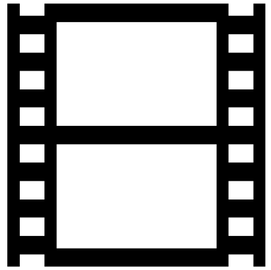
React-Native, NativeScript

Data Processing

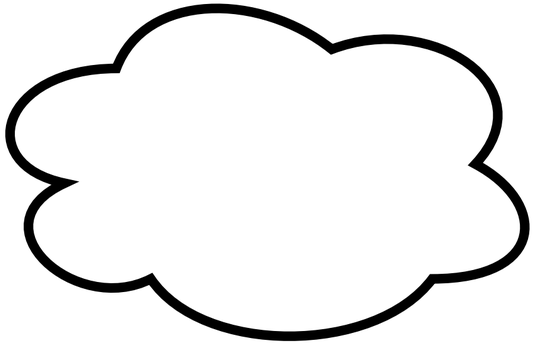
OpenHPS



Knowledge



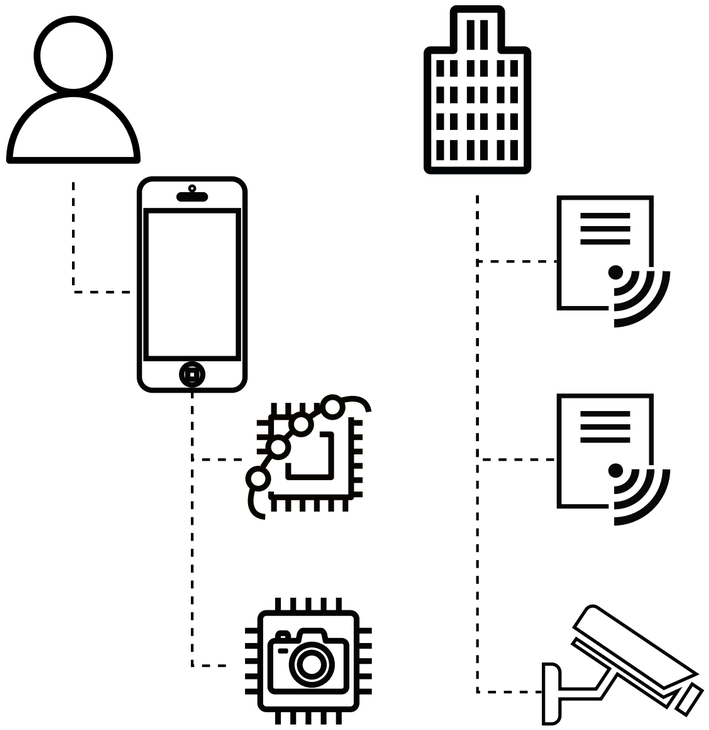
Raw Data



Processed Data

DataObject

OpenHPS



```
// Data object for the person we are tracking
const me = new DataObject("mvdewync@vub.be");
me.displayName = "Maxim Van de Wynckel";

// Phone belonging to the person
const phone = new DataObject()
phone.displayName = "Maxim's Phone";
phone.setParent(me);

// Watch belonging to the person
const watch = new DataObject();
watch.displayName = "Maxim's Android Watch";
watch.setParent(me);

// Camera of the phone
const camera = new CameraObject("80:bb:7c:37:0e:02
camera.width = 1980;
camera.height = 1024;
camera.fps = 30;
camera.setParent(phone);
```

Absolute and Relative Positions

OpenHPS

Absolute

- 2D, 3D, Geographical, ...

Relative

- Distance, angle, velocity, ...
- Relative to another *object*

```
// Absolute geographical position
phone.setPosition(new GeographicalPosition(
    50.8204, 4.3921
));

// Relative position(s) to another object
phone.addRelativePosition(new RelativeDistance(
    "9F:F1:90:4C:F5:6A", 5.2, LengthUnit.METER
));
phone.addRelativePosition(new RelativeDistance(
    "DC:0F:14:B2:6B:80", 1.4, LengthUnit.METER
));
```

ReferenceSpace

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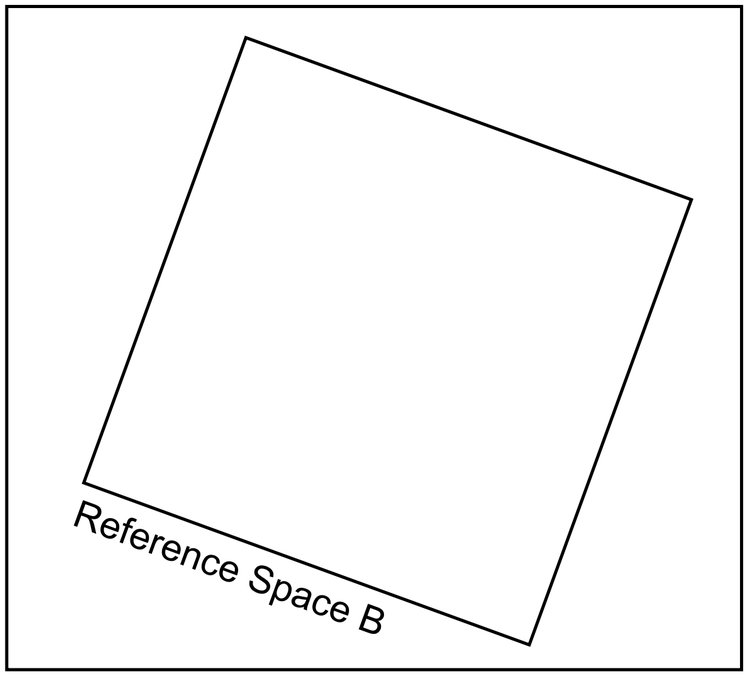
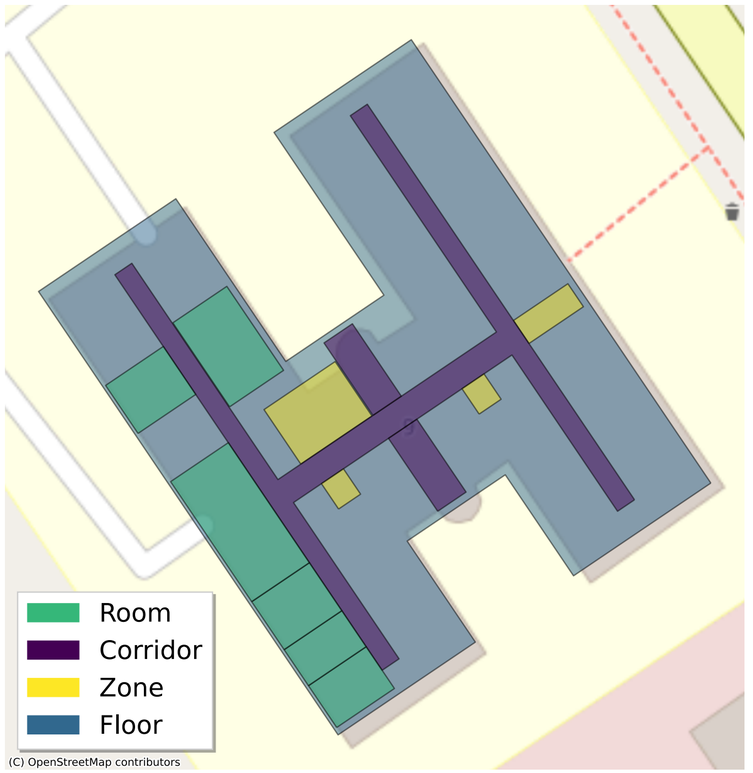
An absolute position can be relative to a reference space.

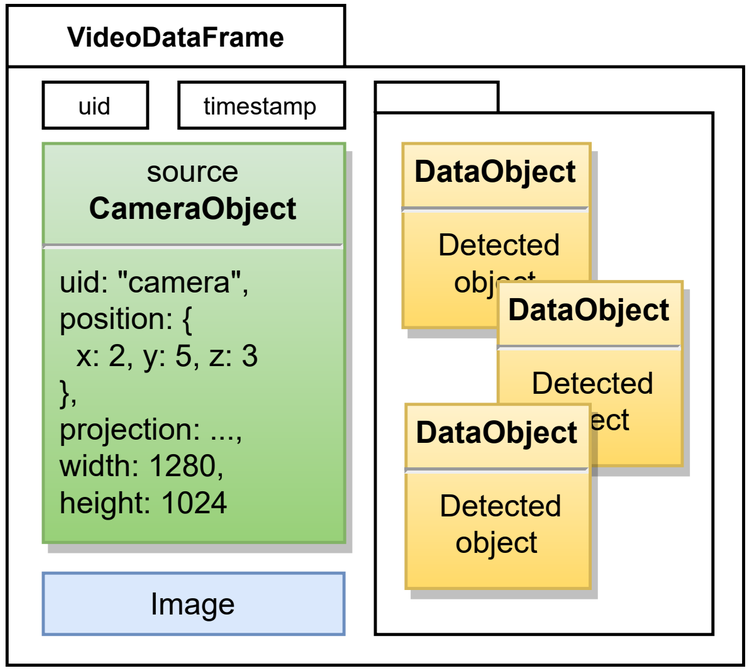


Reference Space A



DataFrame

OpenHPS

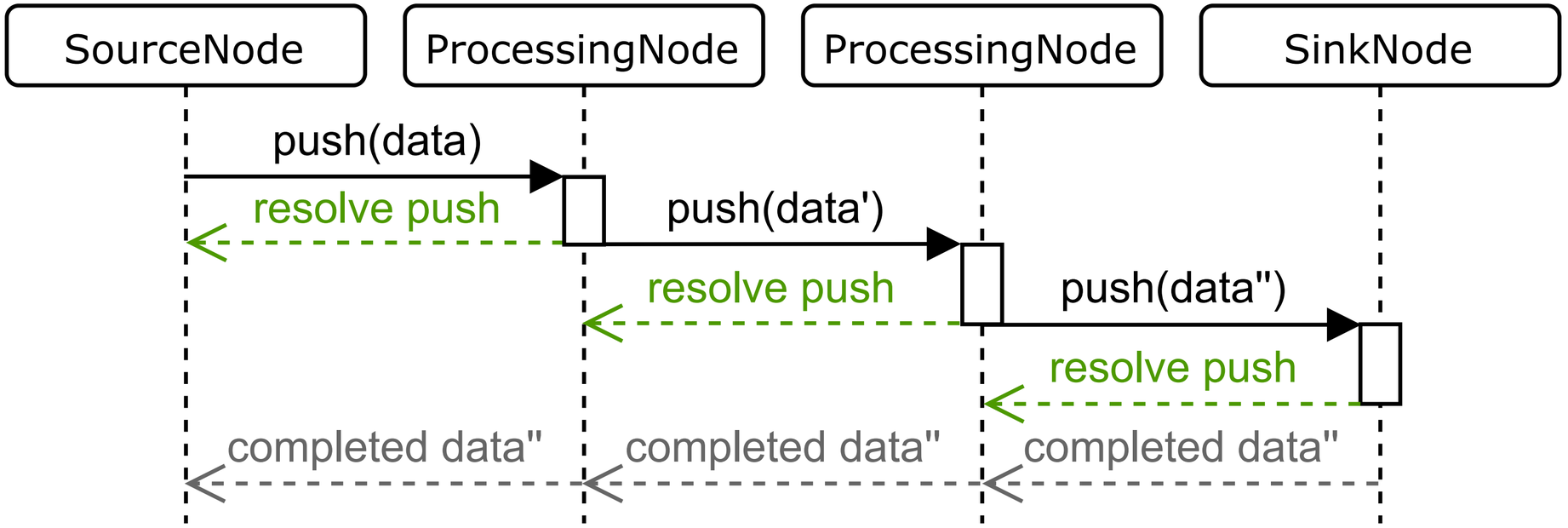



```
// Sensor that captured the frame
const camera = new CameraObject();

// Create a new frame
const frame = new VideoFrame();
frame.source = camera;
frame.image = myImage;

// Add detected objects to frame
frame.addObject(/* ... */);
frame.addObject(/* ... */);
frame.addObject(/* ... */);
```

DataFrame ...

OpenHPS

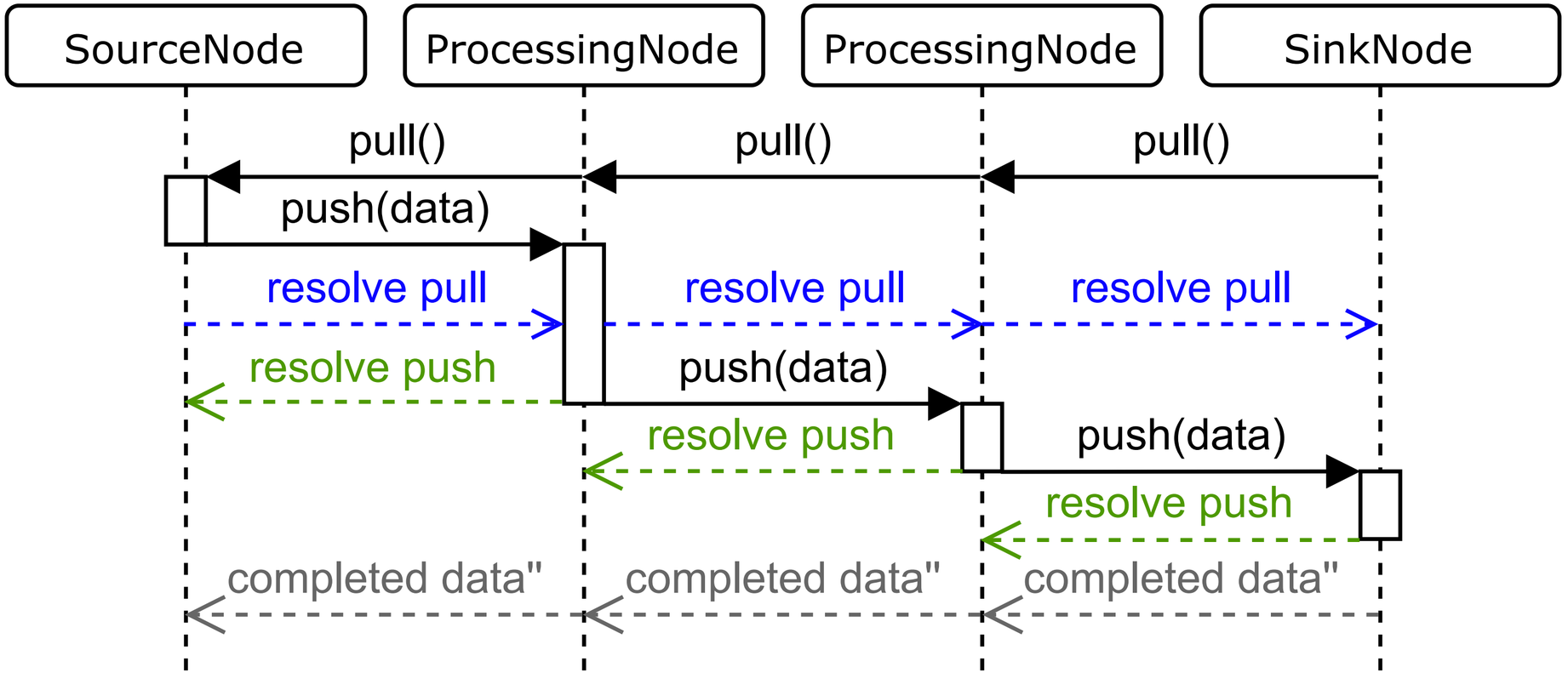
Pushing Data



DataFrame ...

OpenHPS

Pulling Data



Positioning Model

OpenHPS

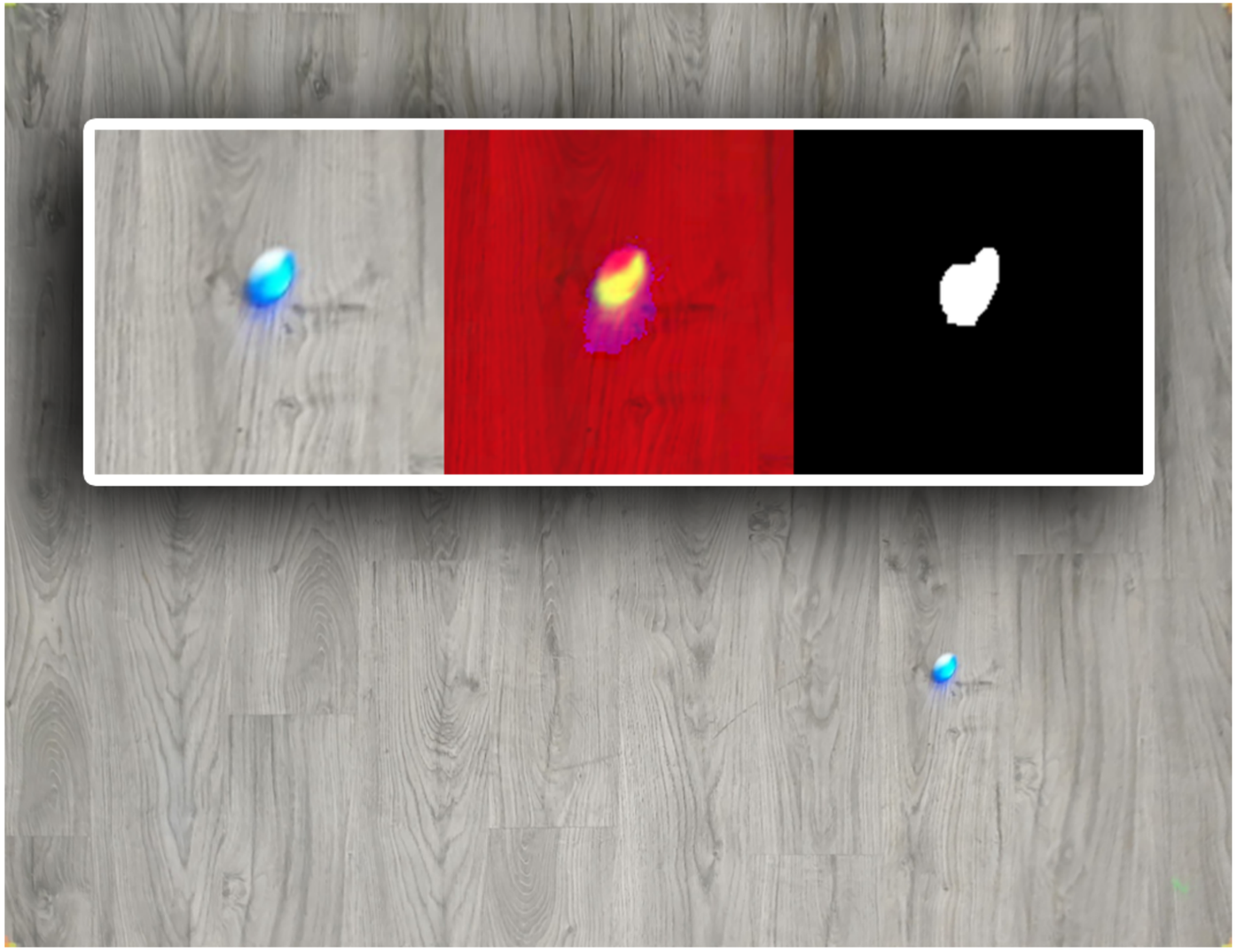
```
ModelBuilder.create()
    .addService(/* ... */)
    .addShape(GraphBuilder.create()
        .from(/* Source node(s) */)
        .via(/* Processing node(s) */)
        .via(/* Processing node(s) */)
        .to(/* Sink node(s) */)
    )
    .addShape(/* Other graph shape */)
    .build().then(model => {
        console.log("Model is ready!");
    }).catch(reject);
```

Example

OpenHPS

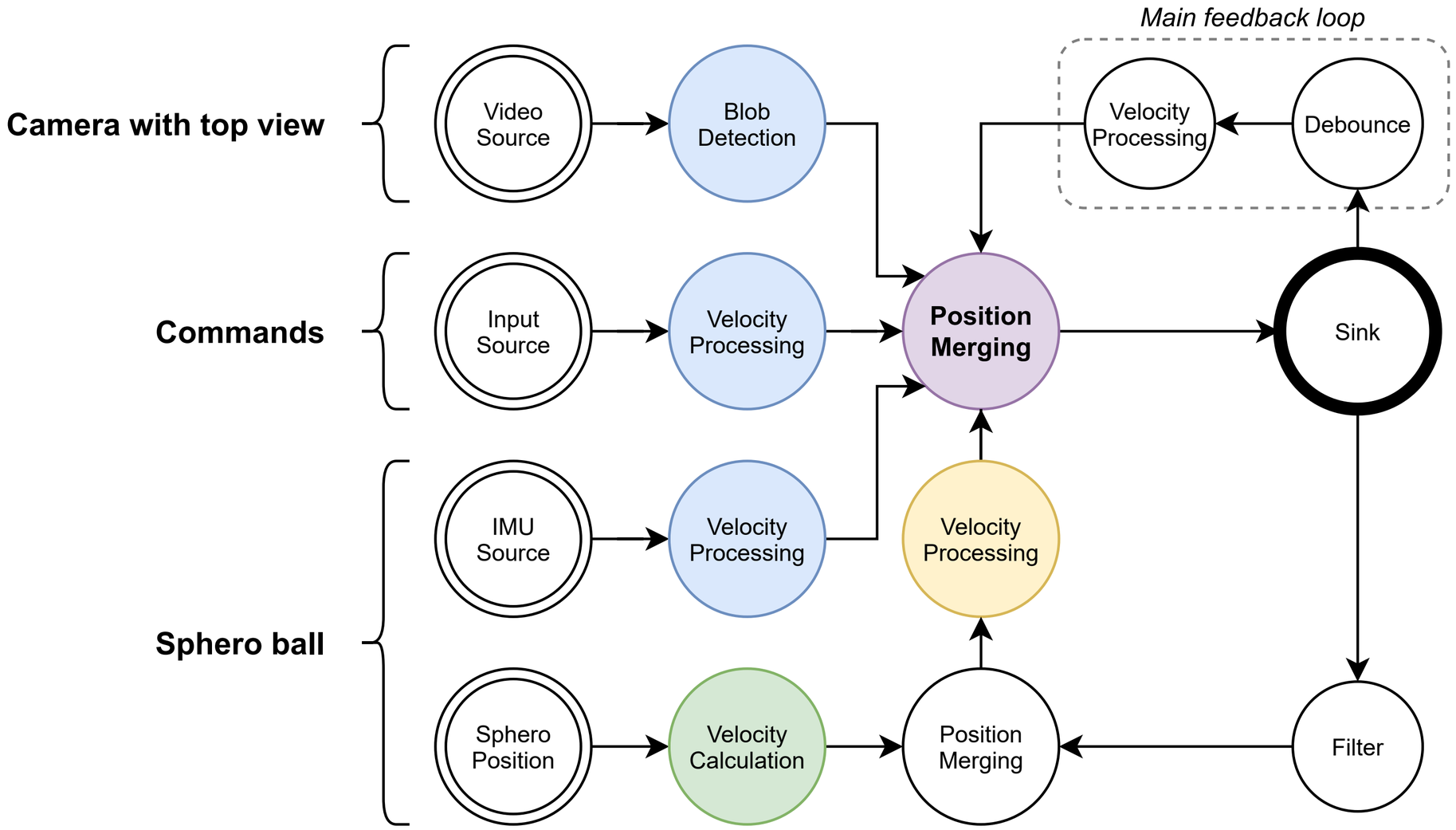
Example

OpenHPS



Example

OpenHPS



Example

OpenHPS

```
GraphBuilder.create()
    .from(new VideoSource(new CameraObject("sphero_video"), {
        autoPlay: true,
        fps: 30,
        throttleRead: true,
        source: new CameraObject("sphero_video")
    }).load("/dev/video2"))
    .via(new ImageTransformNode({
        src: [
            new OpenCV.Point2(307, 120),
            new OpenCV.Point2(1473, 87),
            new OpenCV.Point2(1899, 891),
            new OpenCV.Point2(20, 1024),
        ],
        height: 800,
        width: 1040
    }))
    .via(new ColorMaskProcessing({
        minRange: [90, 50, 50],
        maxRange: [140, 255, 255]
    }))
    .via(new ContourDetectionNode())
    .convertFromSpace(new ReferenceSpace(defaultSpace)
        .translation(1040, 800)
```

Example

OpenHPS

```
class ContourDetectionNode extends ProcessingNode<VideoFrame> {
    public process(frame: VideoFrame): Promise<VideoFrame> {
        return new Promise((resolve) => {
            let contours = frame.image.findContours(
                OpenCV.RETR_EXTERNAL,
                OpenCV.CHAIN_APPROX_SIMPLE);
            if (contours.length >= 1) {
                // Sort contours by area
                contours = contours.sort((a, b) => a.area - b.area);
                // Select the contour with the largest area size
                const m = contours[0].moments();
                const center = new OpenCV.Vec2(
                    m.m10 / m.m00,
                    m.m01 / m.m00);
                // Use the center as the 2D pixel position
                const position = new Absolute2DPosition(
                    center.x,
                    center.y);
                position.unit = LengthUnit.CENTIMETER;
                position.accuracy = Math.sqrt(contours[0].area);
                frame.source.setPosition(position);
            }
            resolve(frame);
        });
```

Contributing and Future Work

OpenHPS

- Positioning algorithms
- Process network communication
- Bindings to other systems
- (UI) abstractions for end-user authoring
- Documentation and examples

Resources and Links

OpenHPS

https://openhps.org

https://github.com/OpenHPS

https://npmjs.com/org/openhps

Technical Report

Example Video