Rapid Prototyping of a Positioning System Using the OpenHPS Framework

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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, under water or on a table?

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**

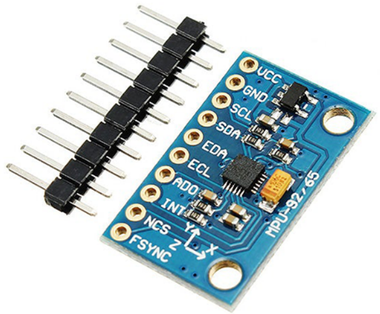
Geospatial mapping of an environment

Technologies

OpenHPS

Technologies used to obtain sensor data for positioning

- Camera (stereoscopic, monocular, omnidirectional)
- Beacons (ultrawideband, Bluetooth, ultrasound)
- LIDAR
- Inertial measurement unit (IMU)
- Visible light communication
- ...

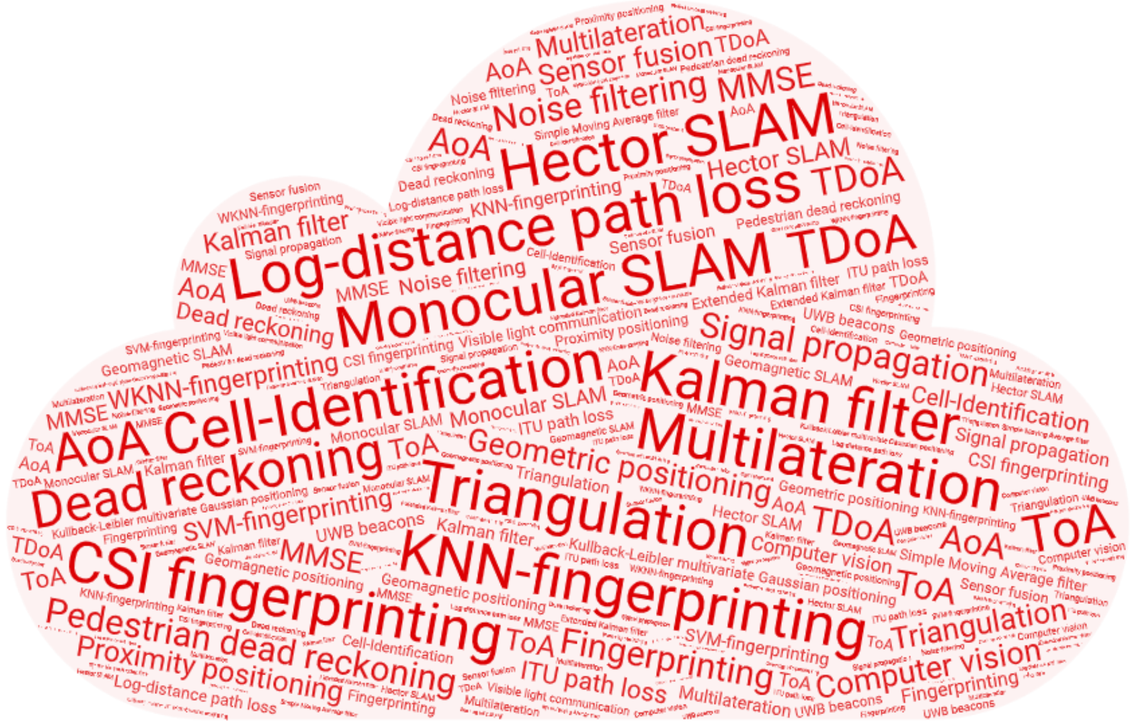


Algorithms

OpenHPS

Algorithms used to process sensor data

- Lateration
- Proximity positioning
- Signal propagation
- 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*
- TraceMeNow *https://isislab-unisa.github.io/trace-me-now*

OpenHPS

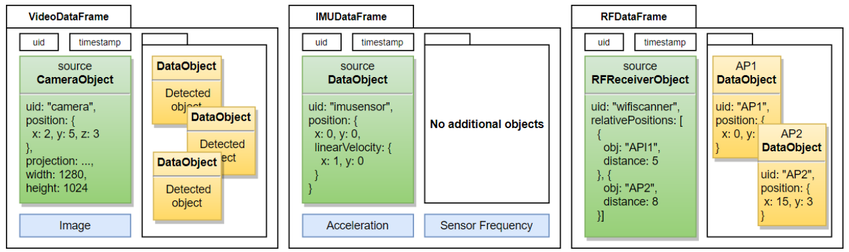
OpenHPS

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 {
```

License Apache 2.0

Built With TypeScript

Website openhps.org

OpenHPS

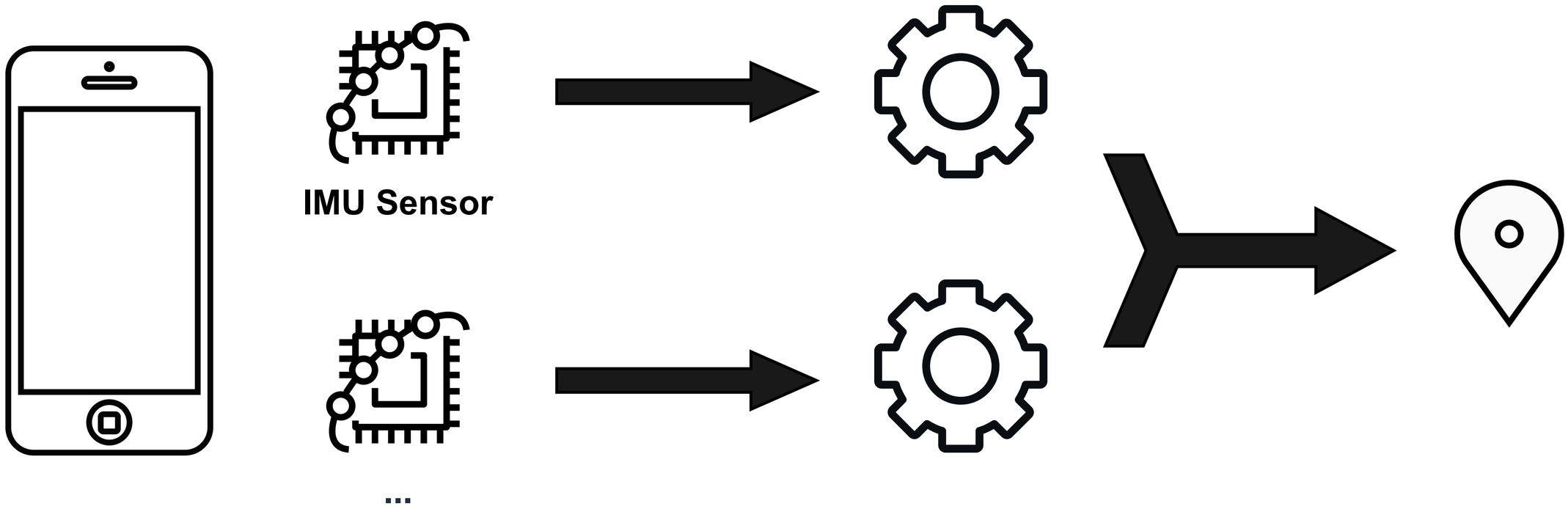
OpenHPS

An Open Source Hybrid Positioning System

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

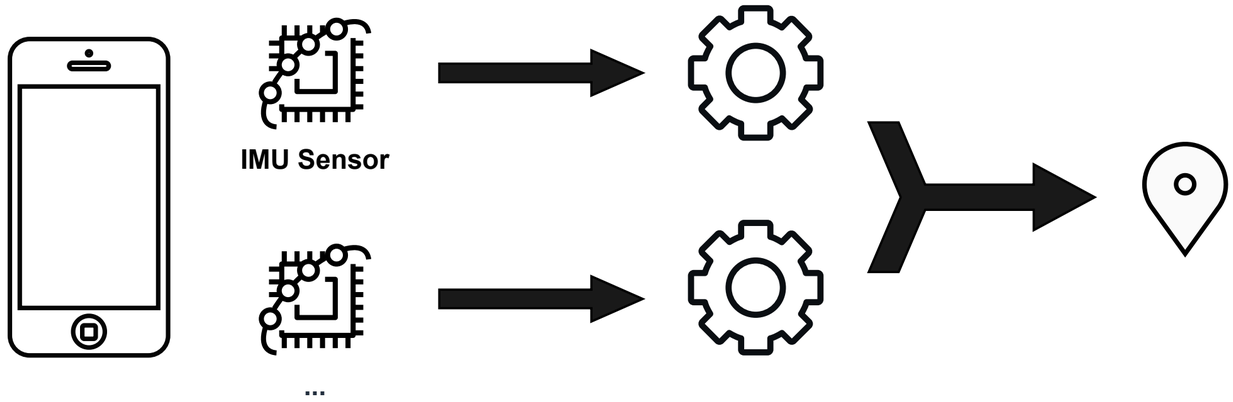
Process Network Design

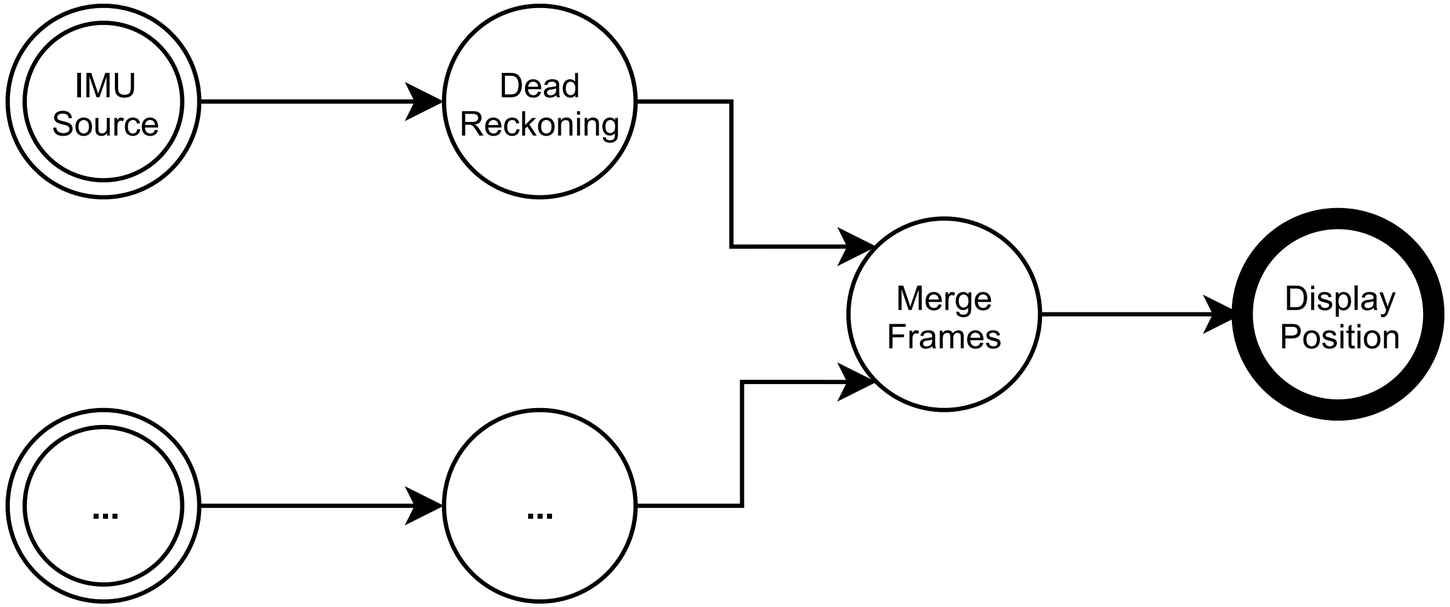
OpenHPS



Process Network Design ...

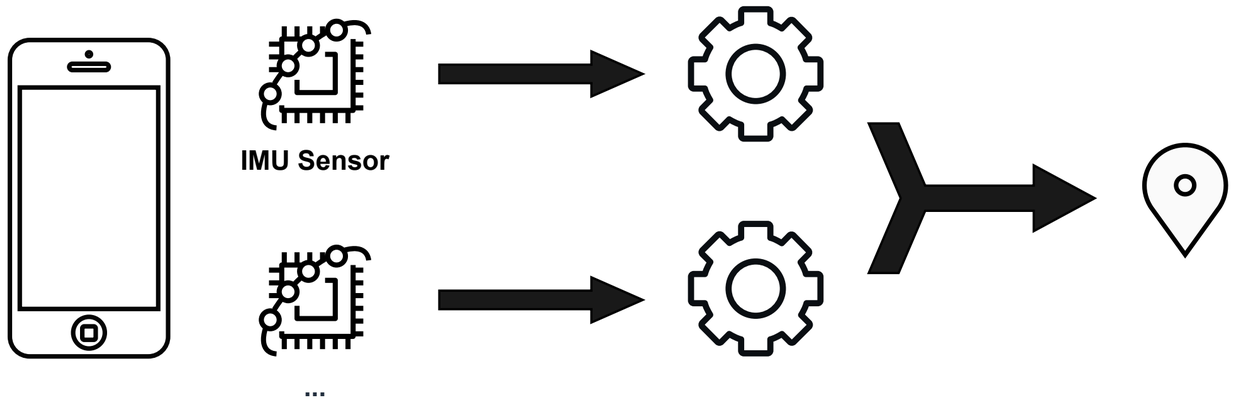
OpenHPS

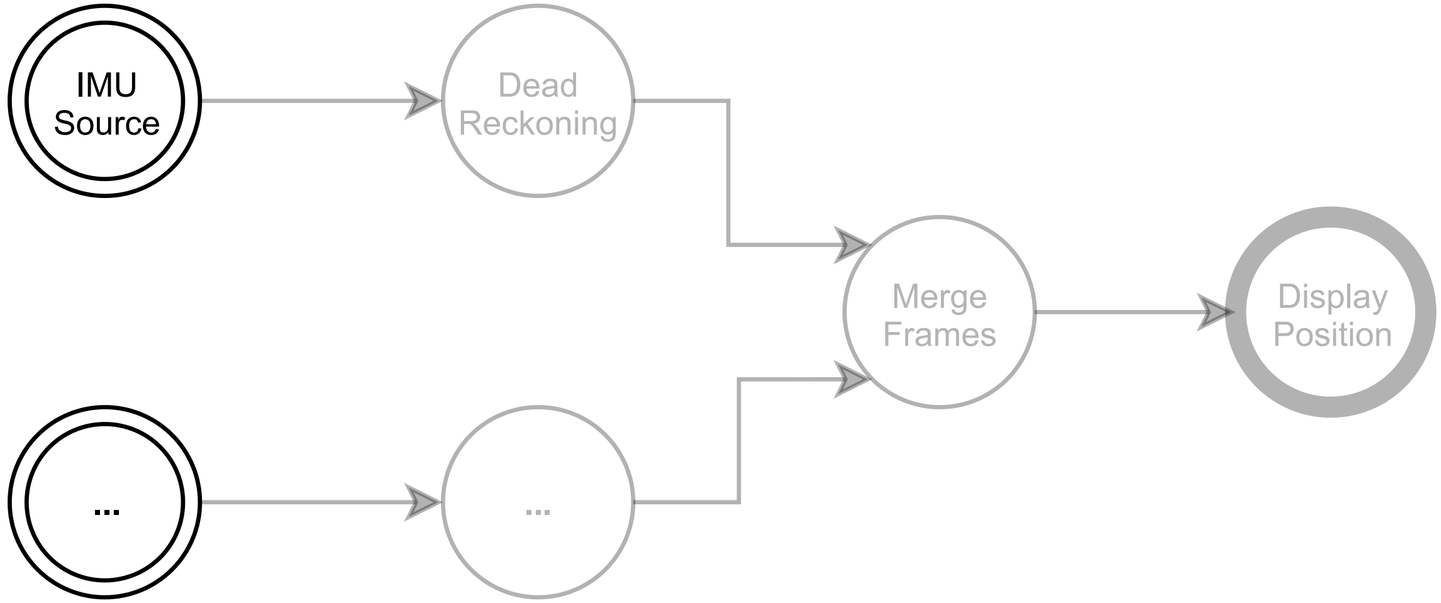




Process Network Design ...

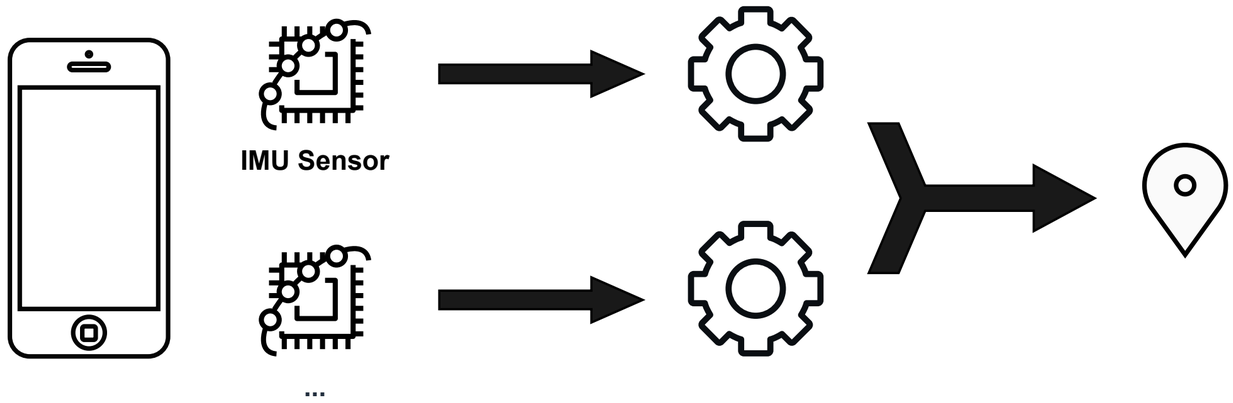
OpenHPS

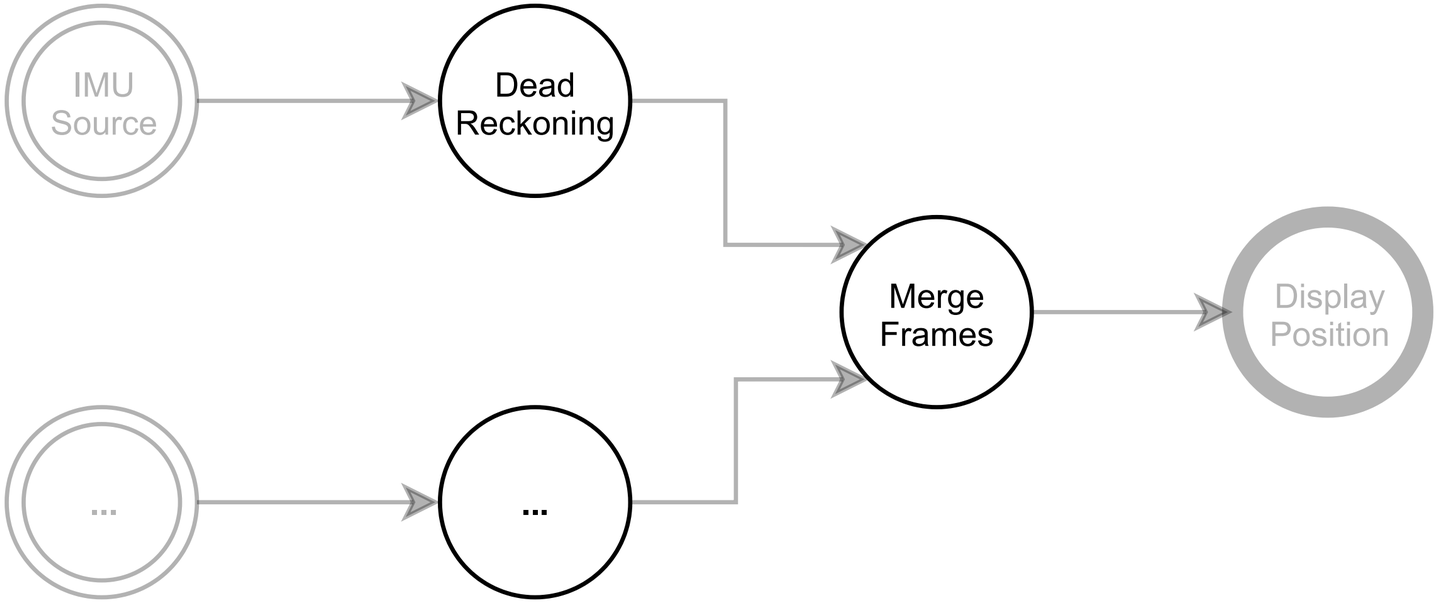




Process Network Design ...

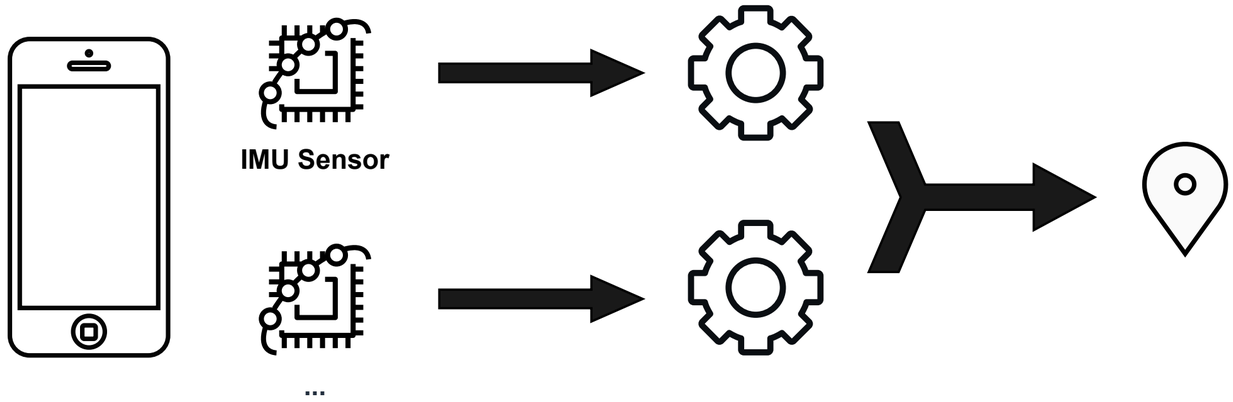
OpenHPS

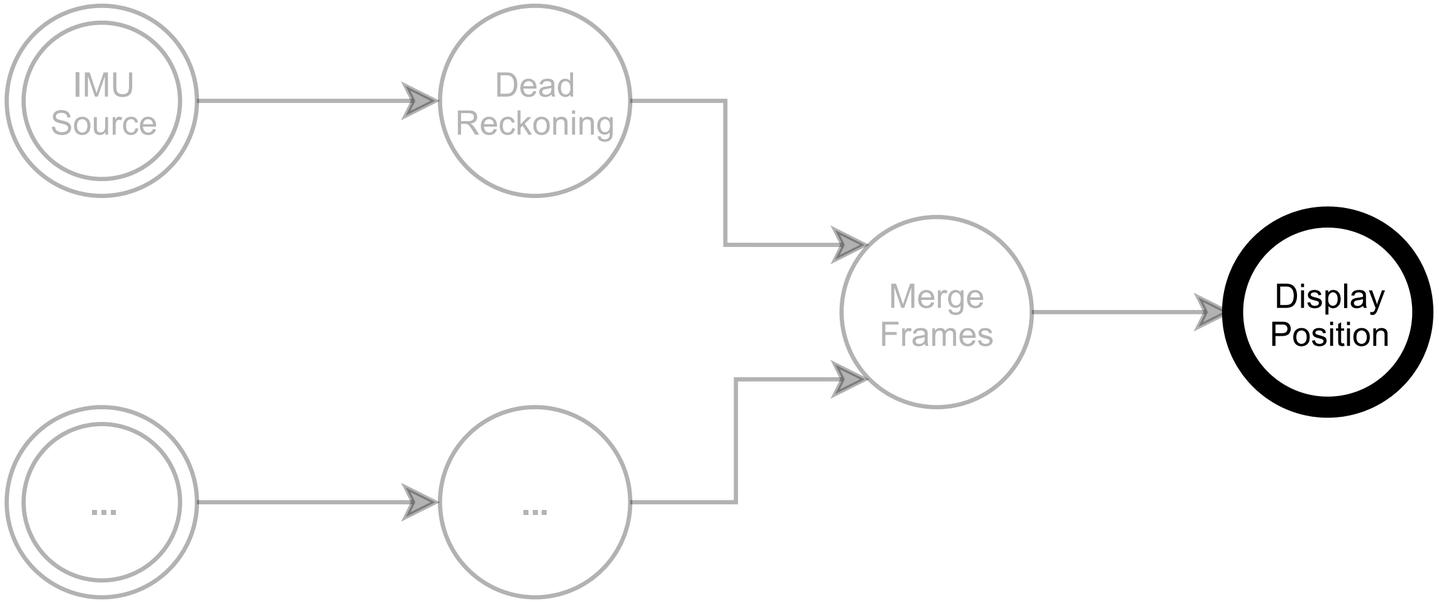




Process Network Design ...

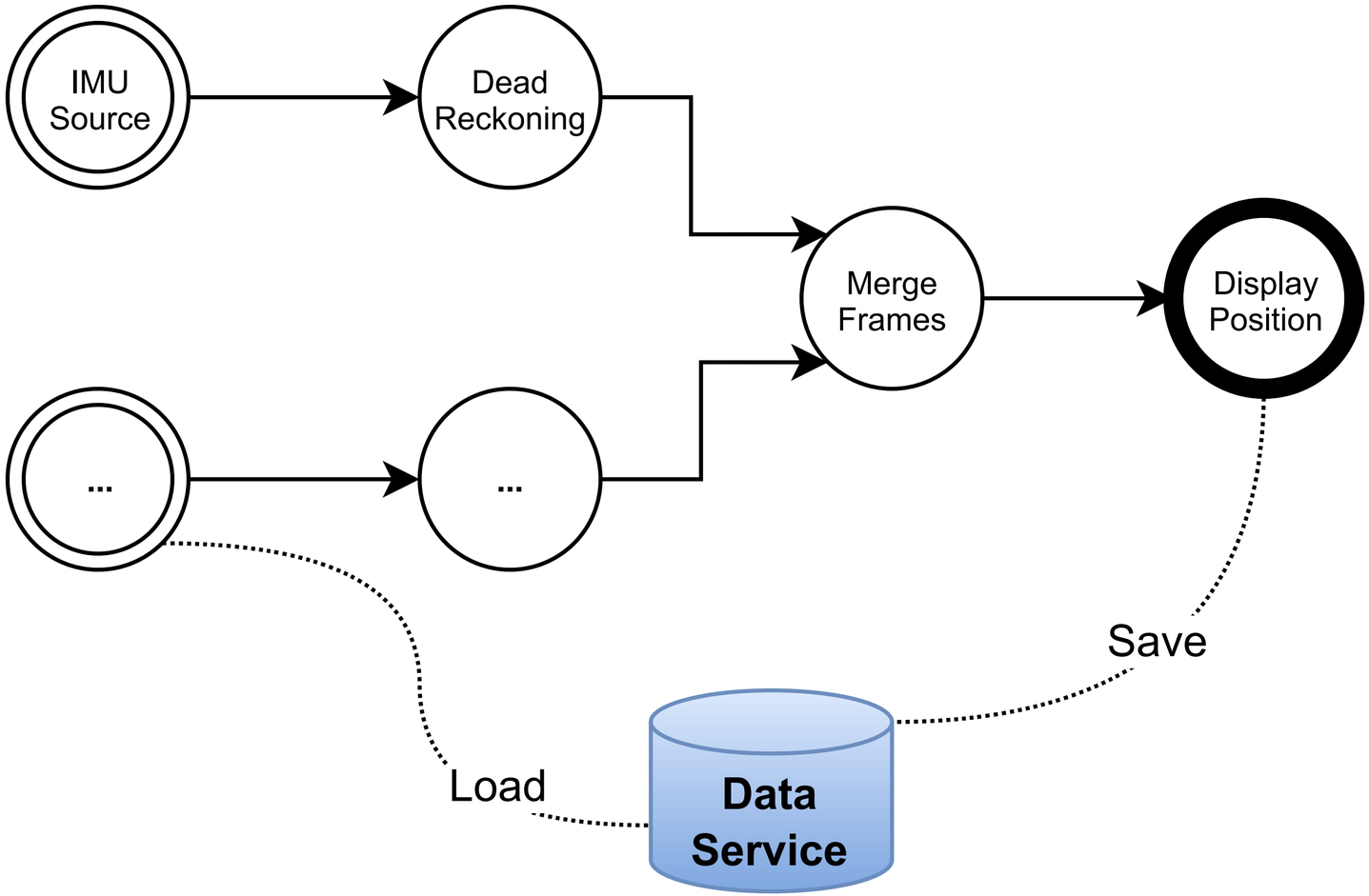
OpenHPS





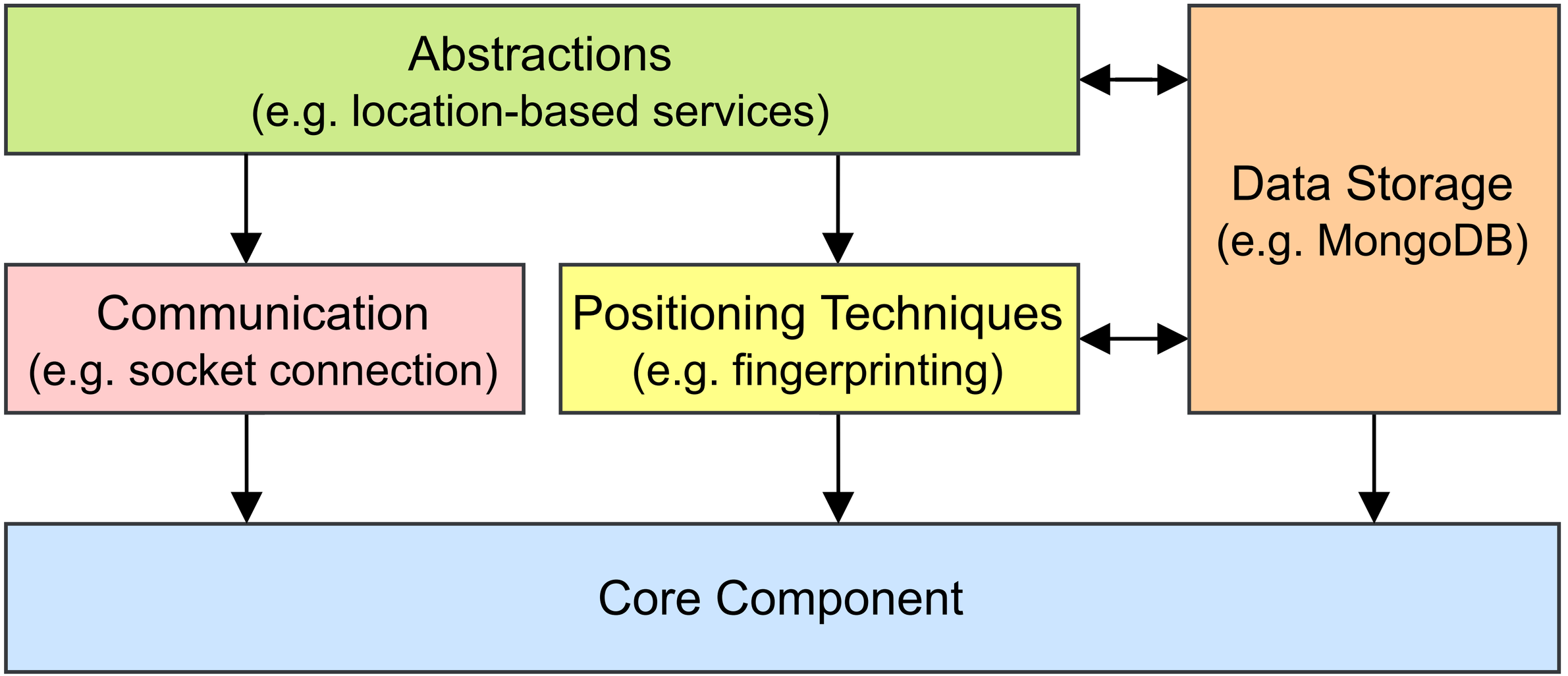
Process Network Design ...

OpenHPS



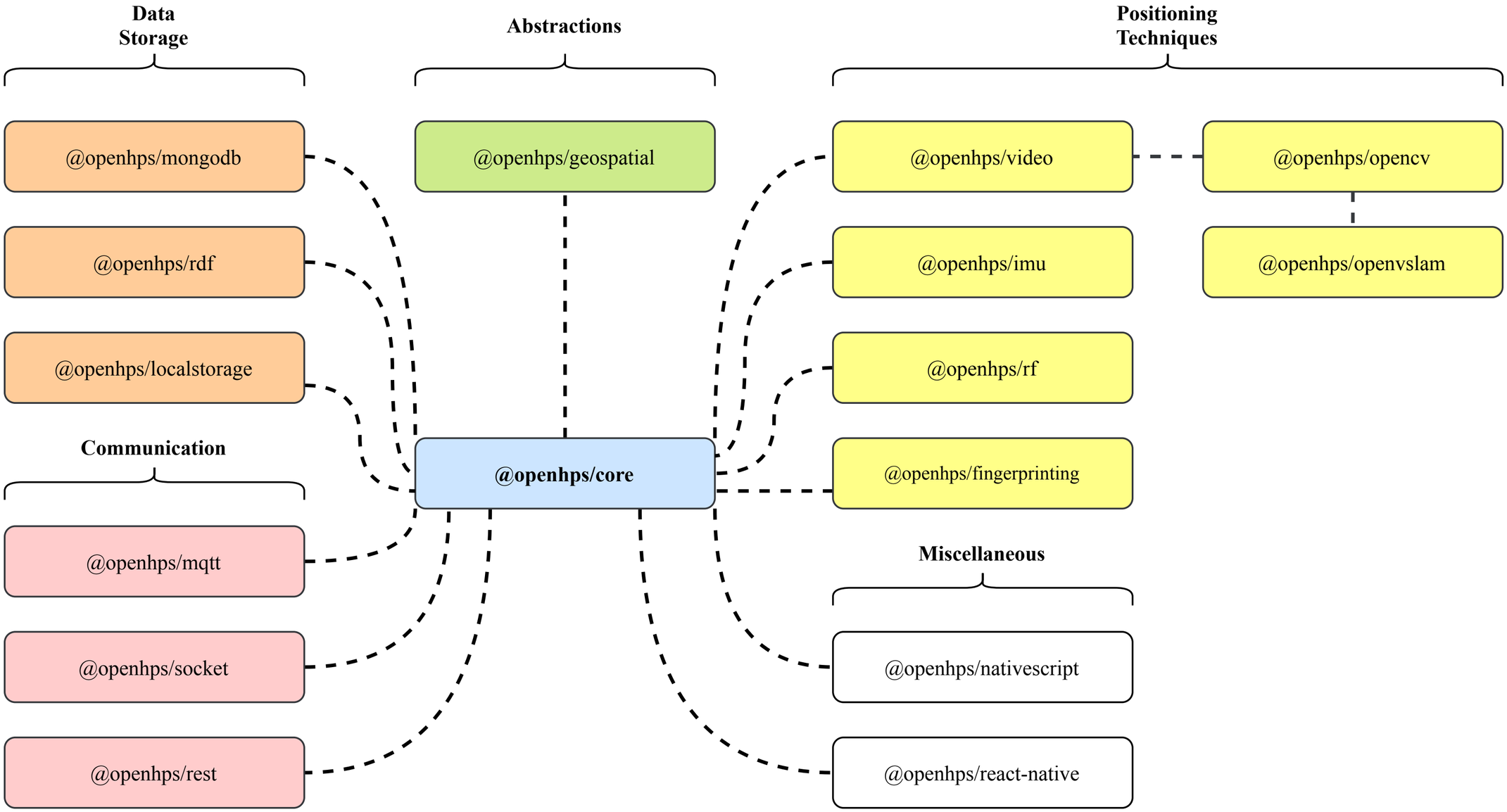
Modularity

OpenHPS



Modularity ...

OpenHPS



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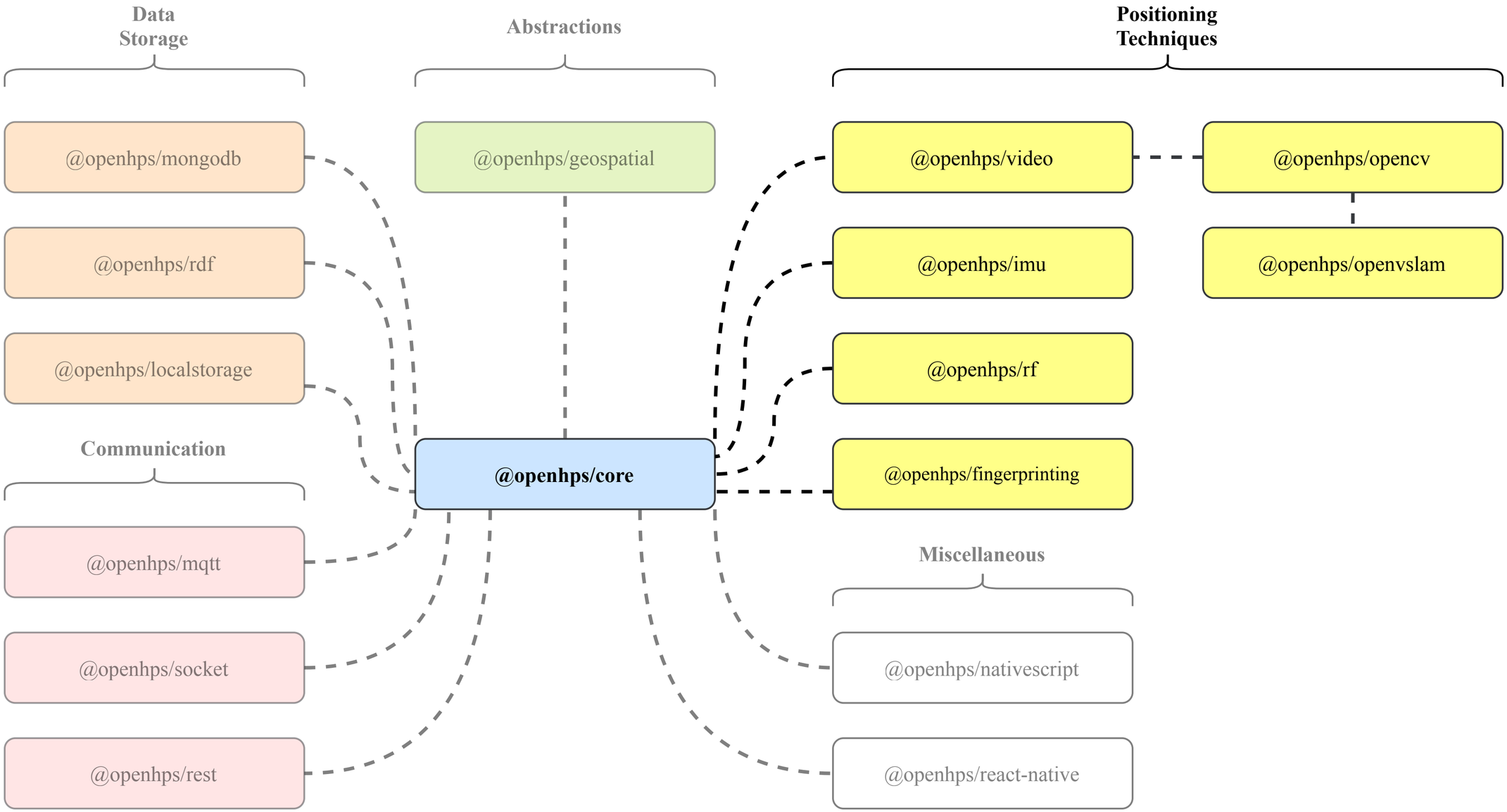
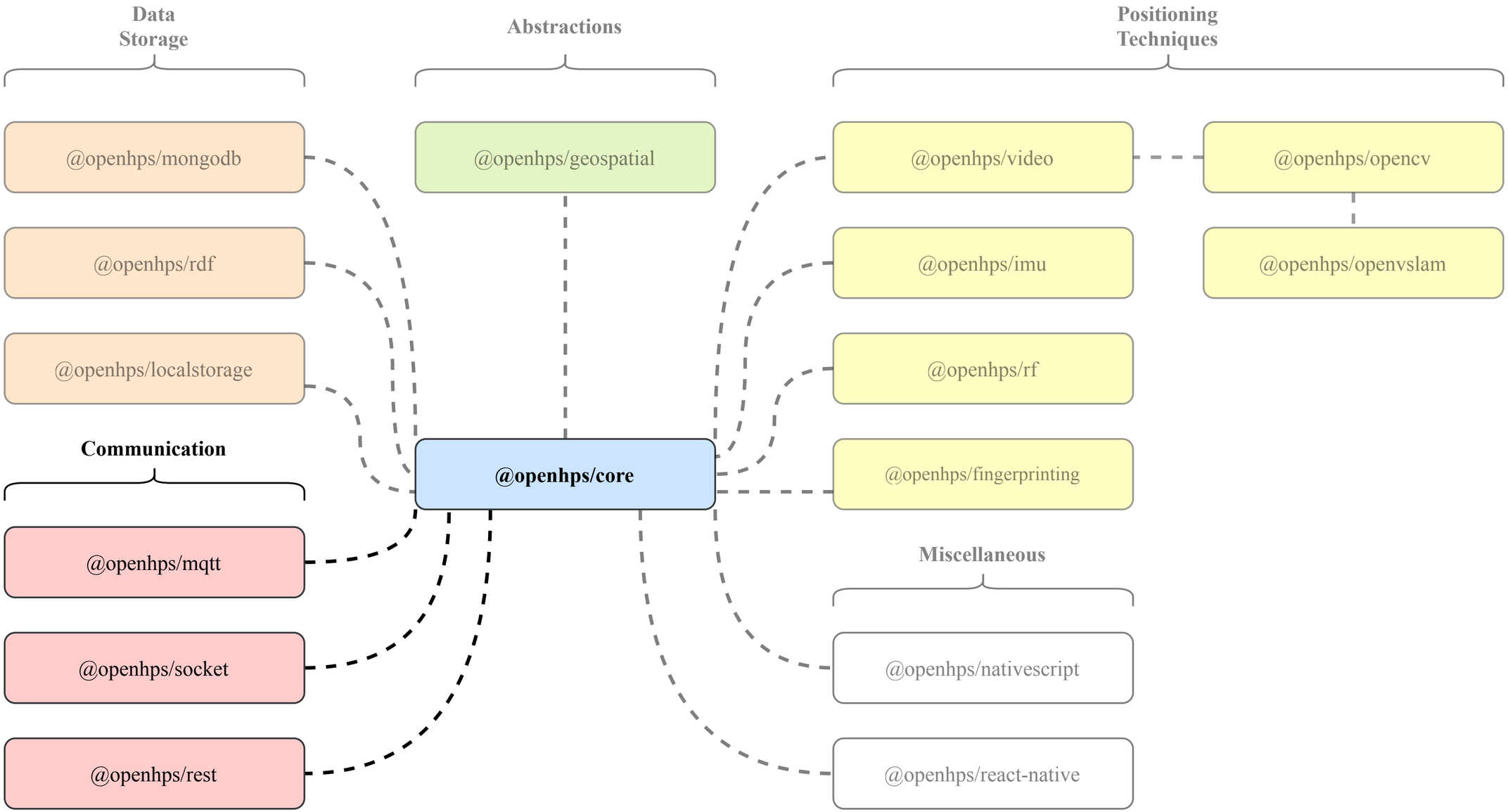
OpenHPS



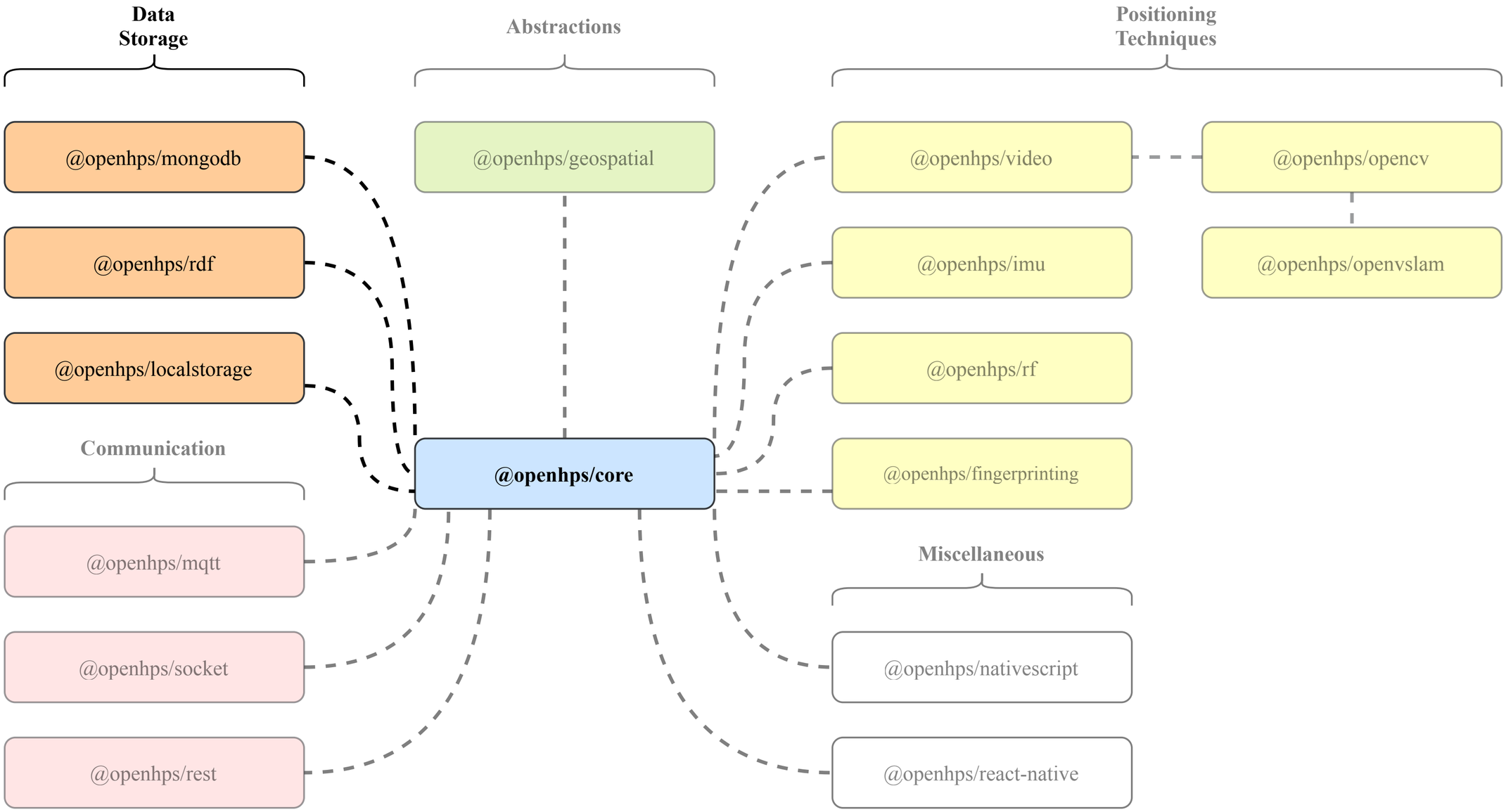
Modularity ...

OpenHPS



Modularity ...

OpenHPS



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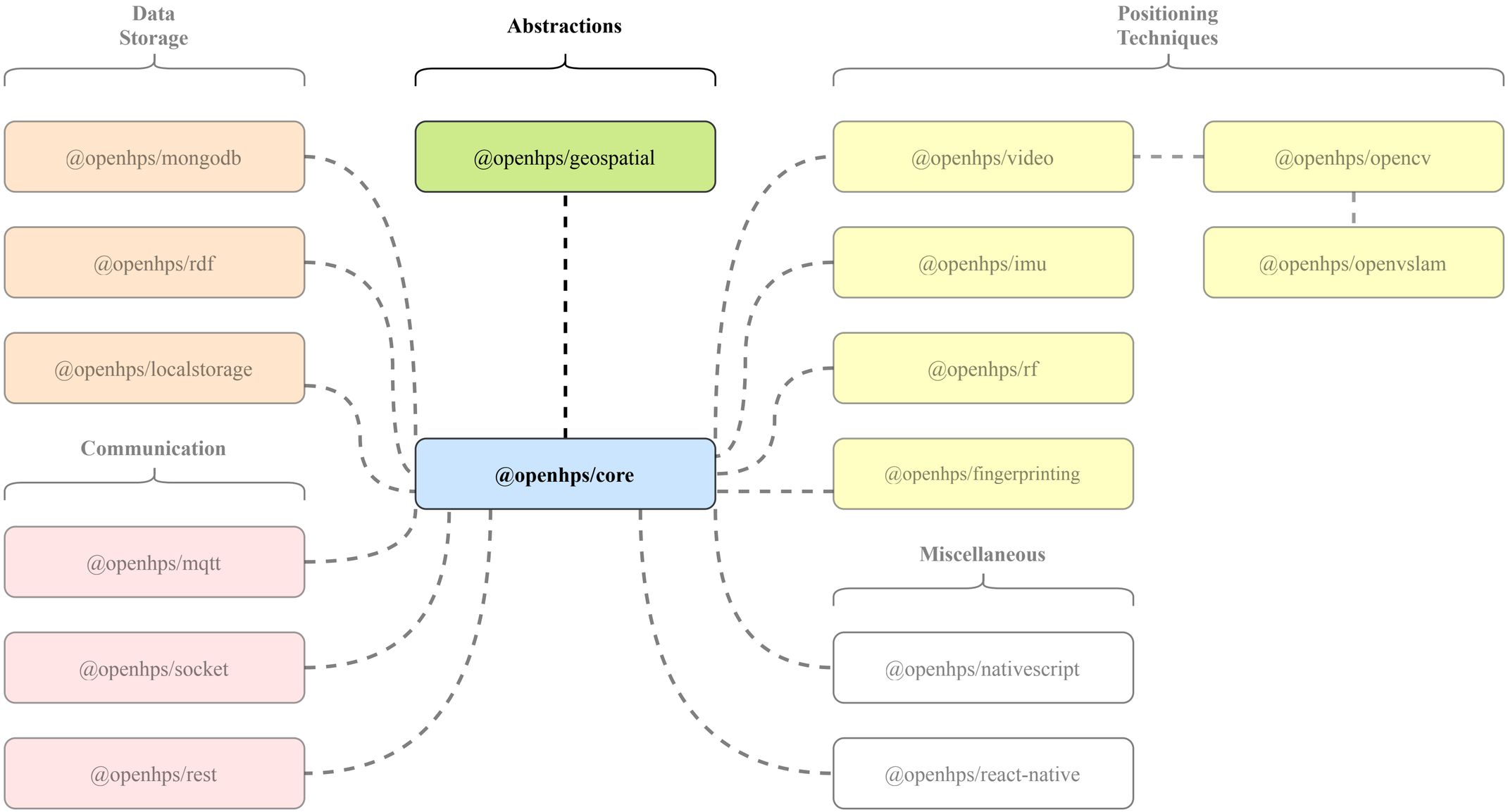
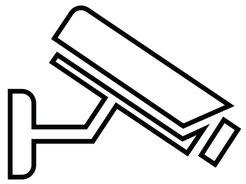
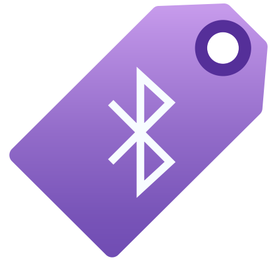
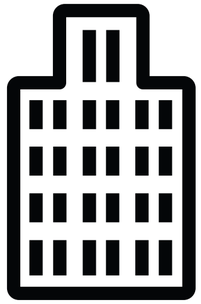


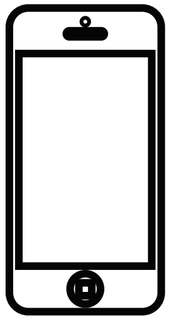
Data Processing

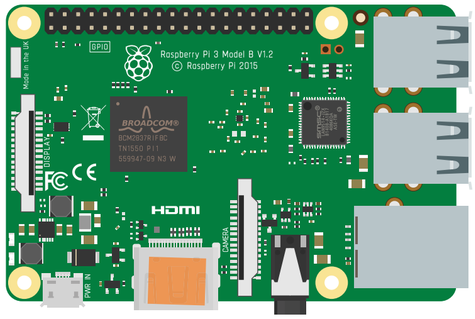
OpenHPS

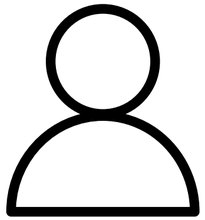


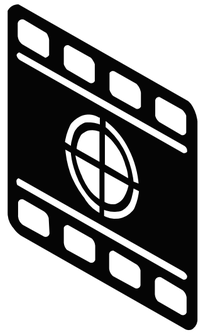






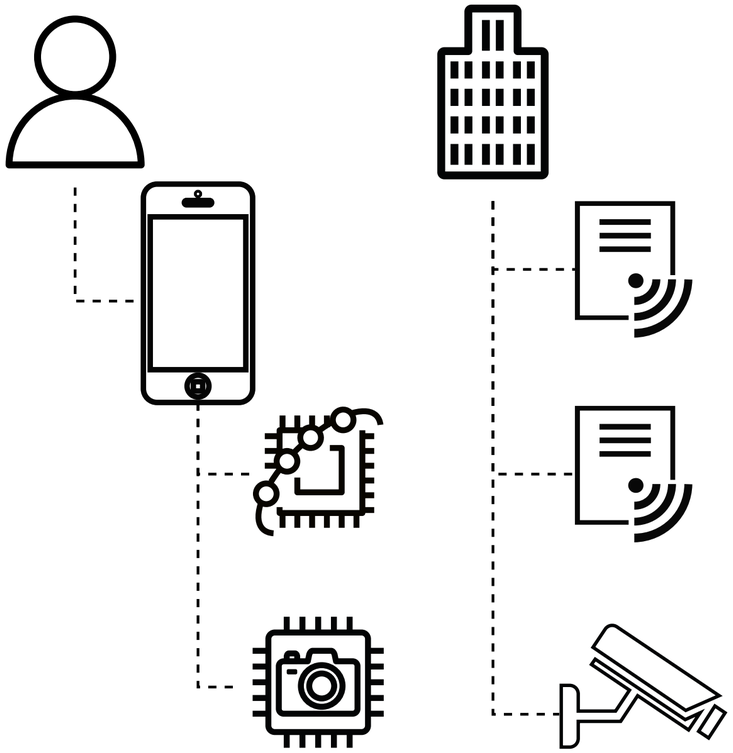






DataObject

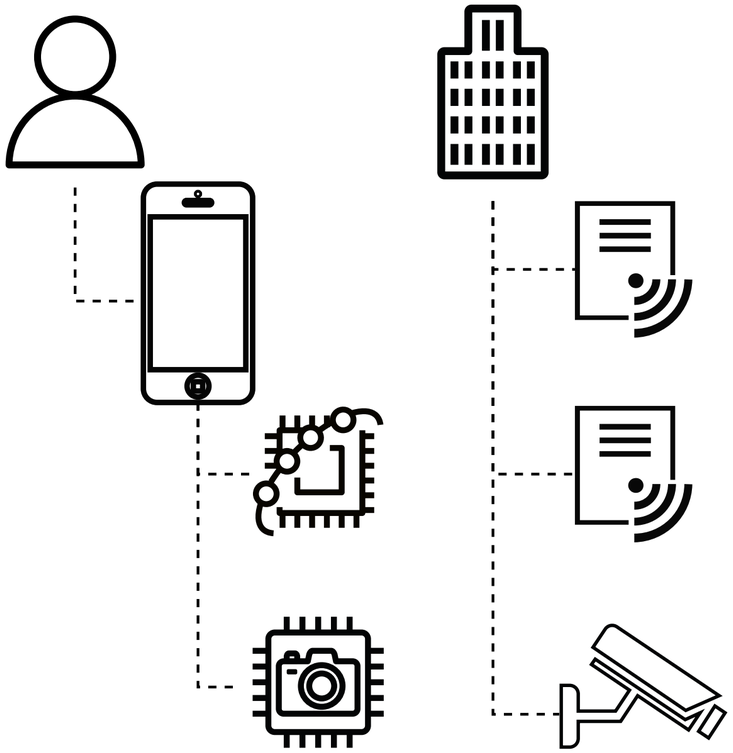
OpenHPS



```
// 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);

// IP camera identified by MAC
const camera = new CameraObject("80:bb:7c:37:0e:02");
camera.width = 1980;
camera.height = 1024;
camera.fps = 30;
camera.setPosition(/* ... */);
```

DataObject

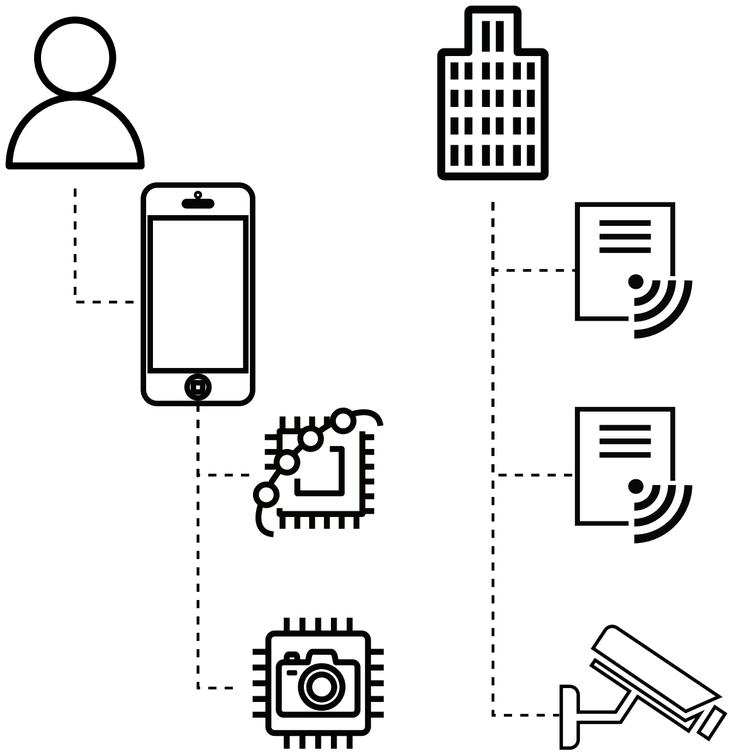
OpenHPS



```
// 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);

// IP camera identified by MAC
const camera = new CameraObject("80:bb:7c:37:0e:02");
camera.width = 1980;
camera.height = 1024;
camera.fps = 30;
camera.setPosition(/* ... */);
```

DataObject

OpenHPS



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watch.setParent(me);

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const camera = new CameraObject("80:bb:7c:37:0e:02");
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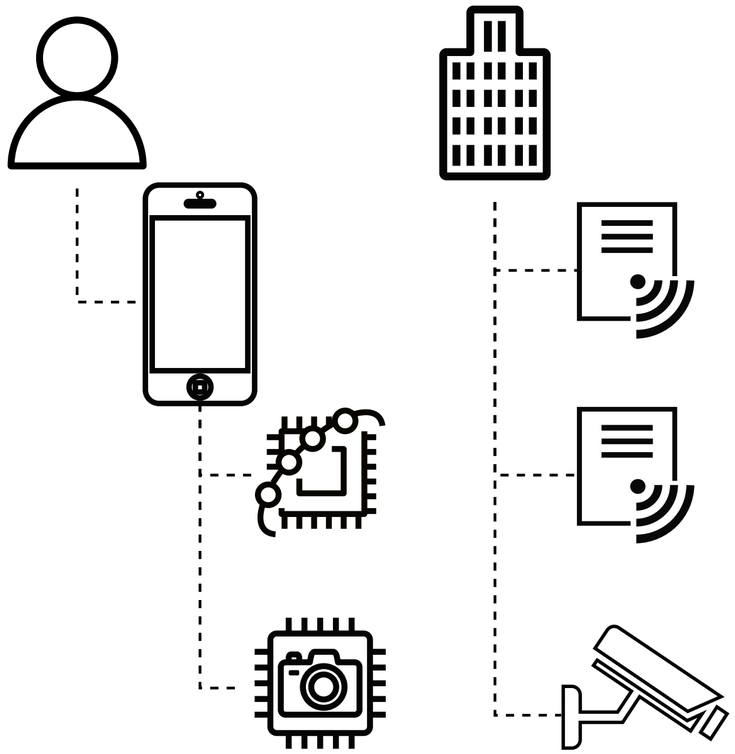
DataObject

OpenHPS



```
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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);

// IP camera identified by MAC
const camera = new CameraObject("80:bb:7c:37:0e:02");
camera.width = 1980;
camera.height = 1024;
camera.fps = 30;
camera.setPosition(/* ... */);
```

Absolute and Relative Positions

OpenHPS

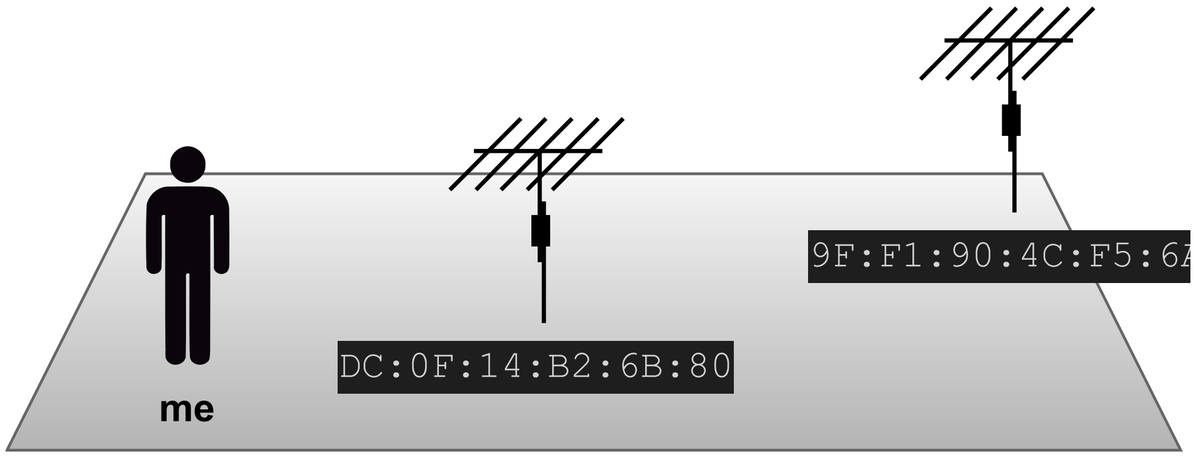
Absolute

- 2D, 3D, geographical, ...
- Within a reference space

Relative

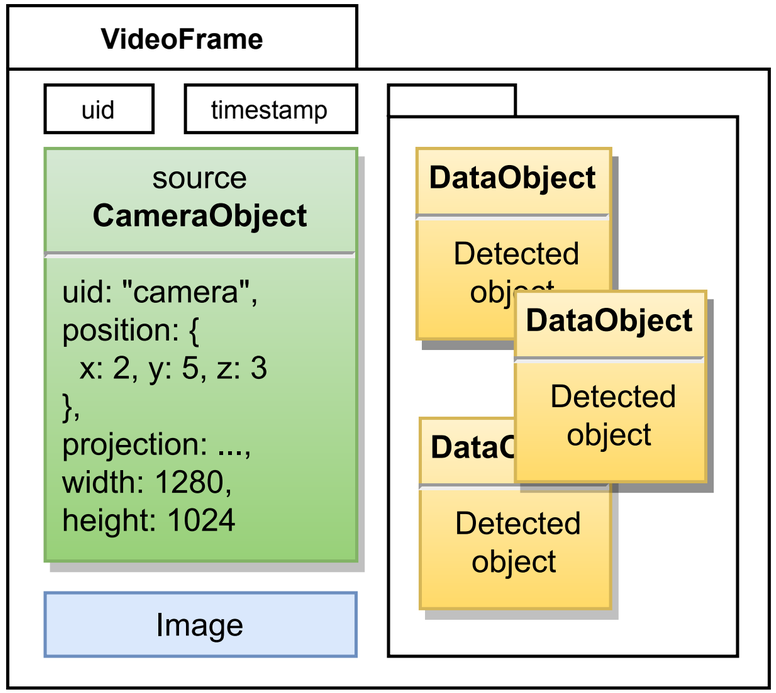
- Distance, angle, velocity, ...
- Relative to another *object*

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

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

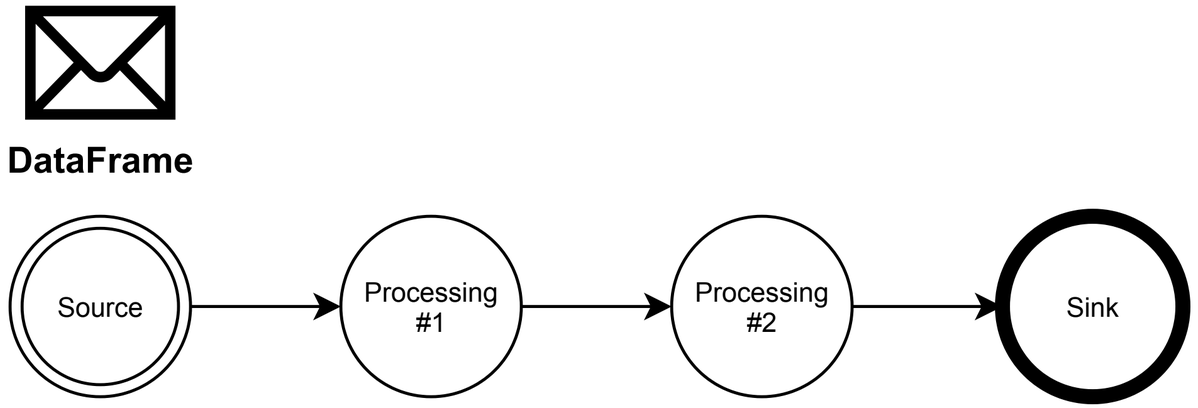


DataFrame

OpenHPS



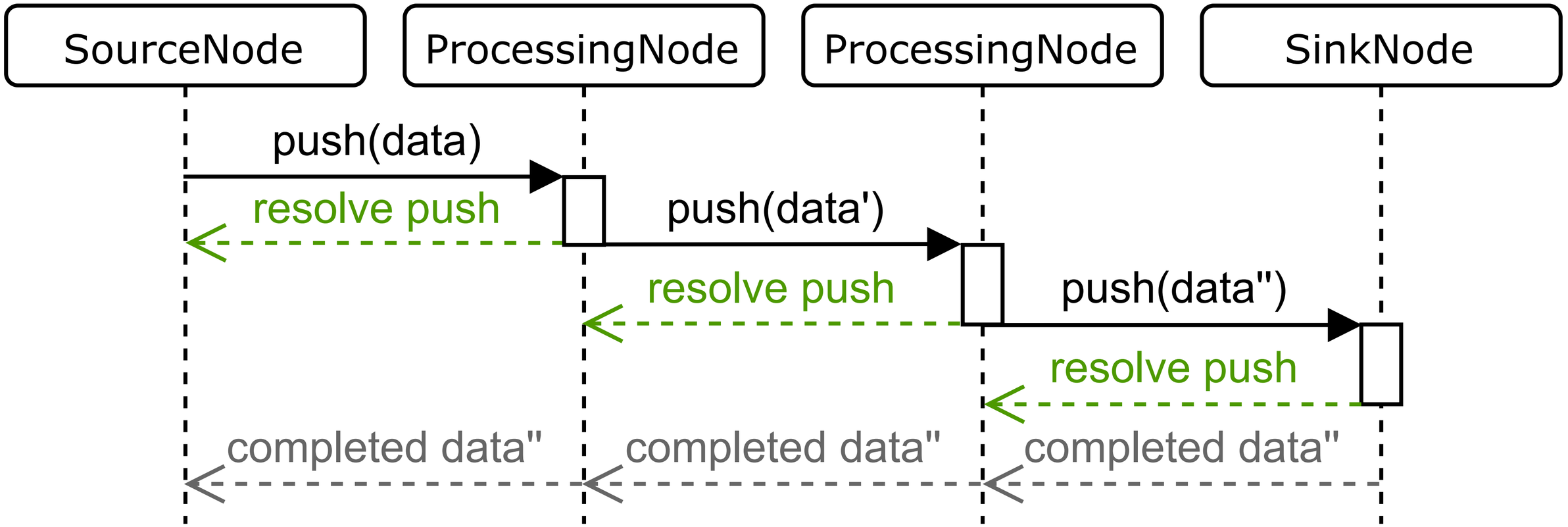

```
// Sensor that captured the frame
const camera = new CameraObject();

// 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

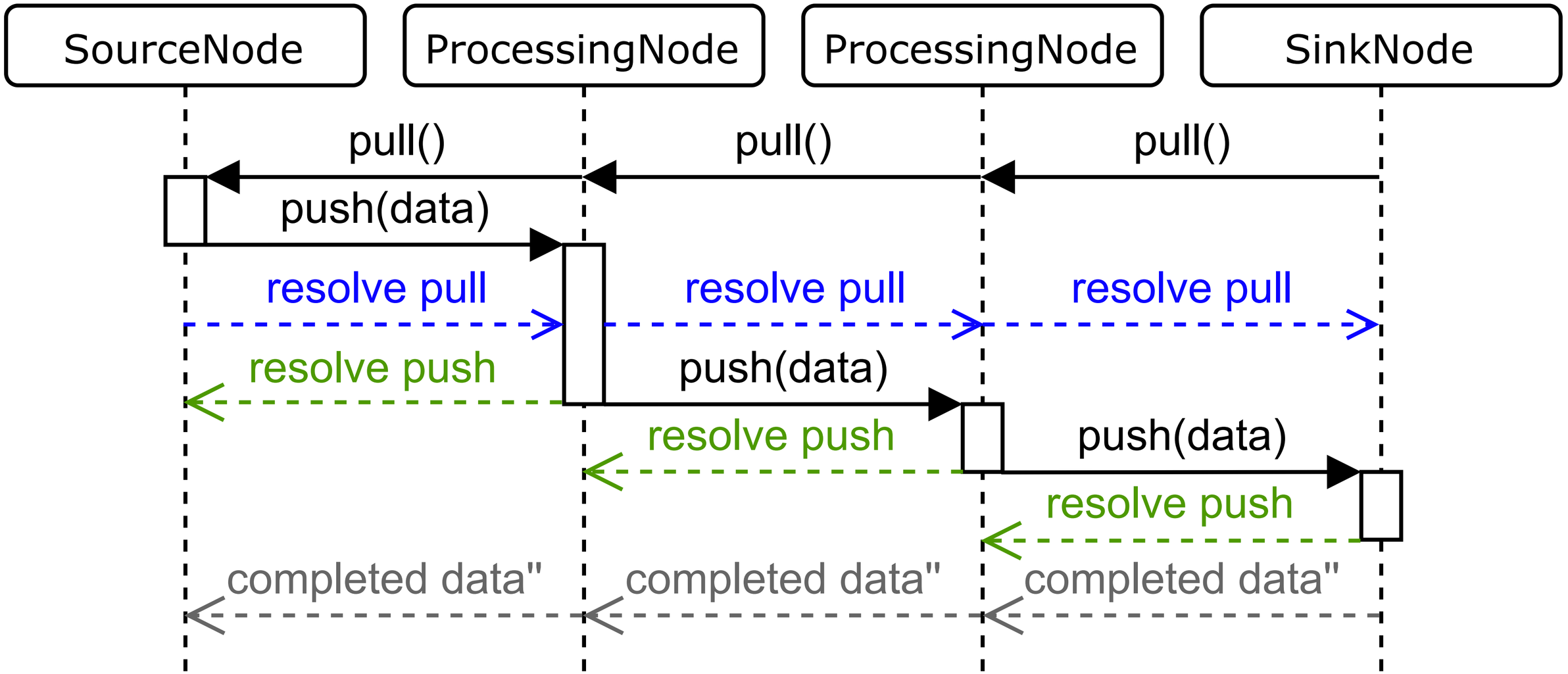
Pushing Data



DataFrame ...

OpenHPS

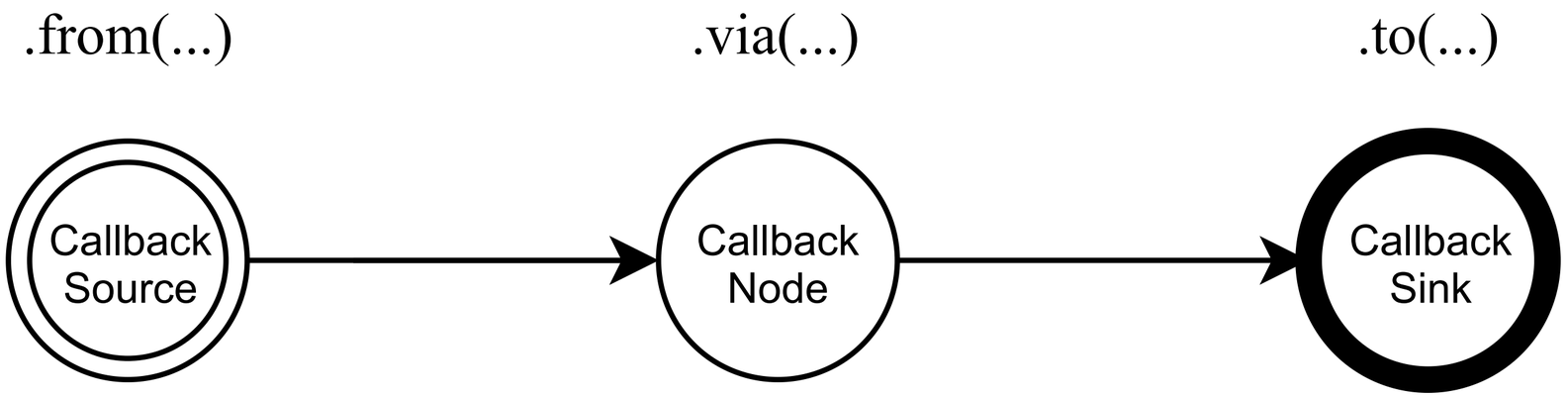
Pulling Data



Positioning Model

OpenHPS

```
ModelBuilder.create()
    .from(new CallbackSourceNode(() => {
        const myObject = new DataObject("mvdewync");
        const frame = new DataFrame();
        frame.addObject(myObject);
        return frame;
    }))
    .via(new CallbackNode((frame: DataFrame) => { /* ... */ }))
    .to(new CallbackSinkNode((frame: DataFrame) => { /* ... */ }))
    .build().then((model: Model) => { /* ... */ });
```

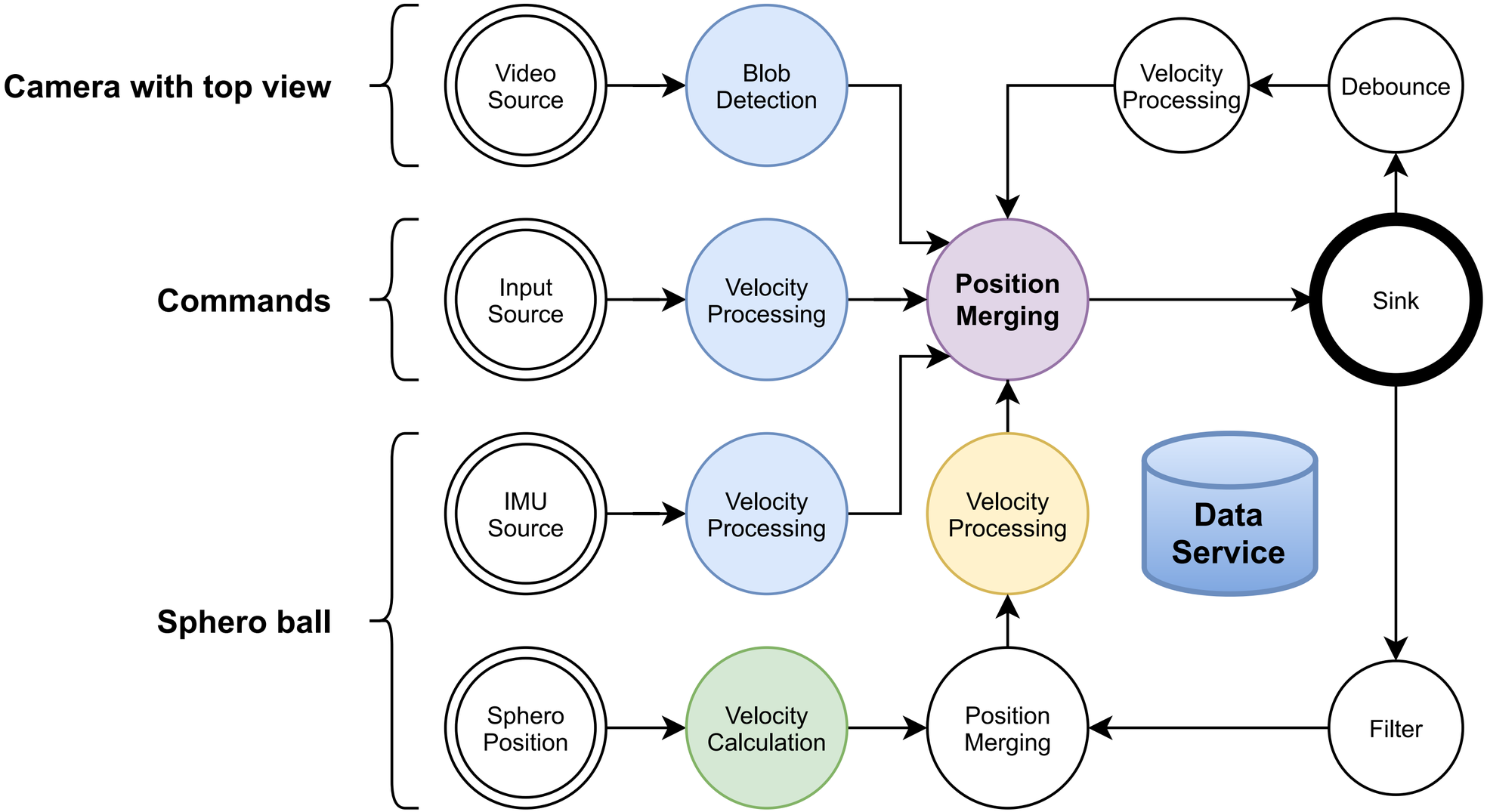


Example

OpenHPS

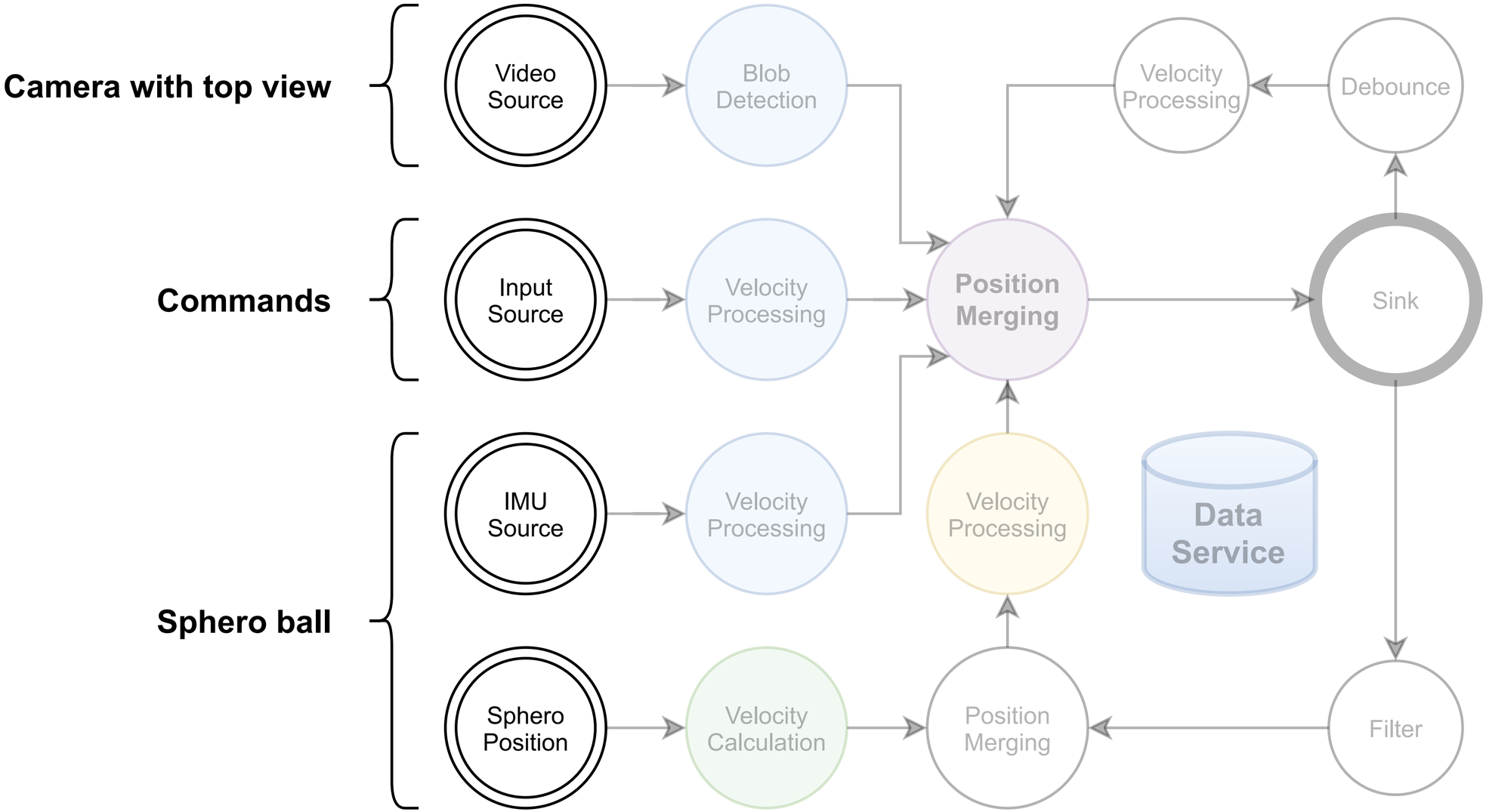
Example ...

OpenHPS



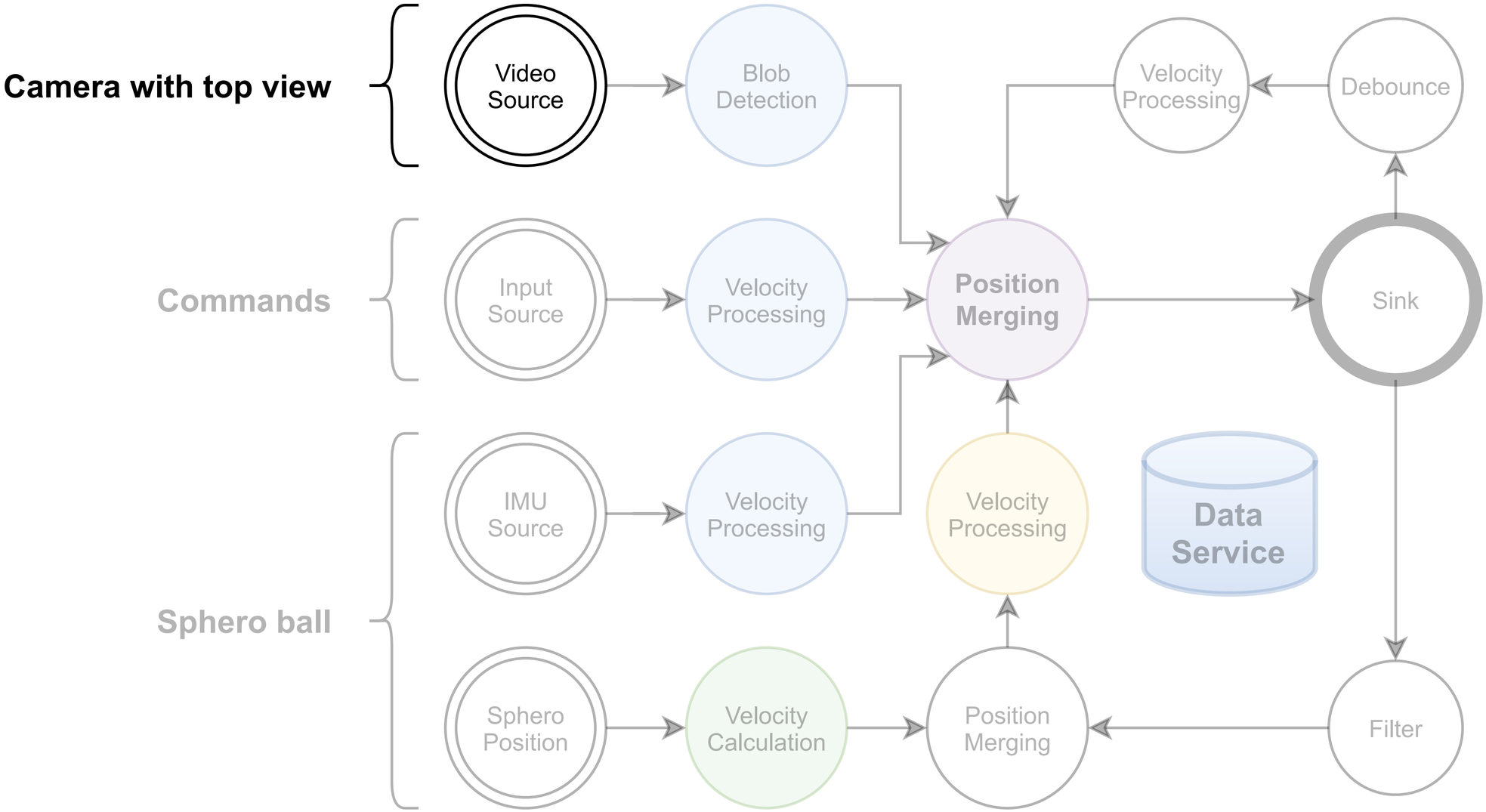
Example ...

OpenHPS



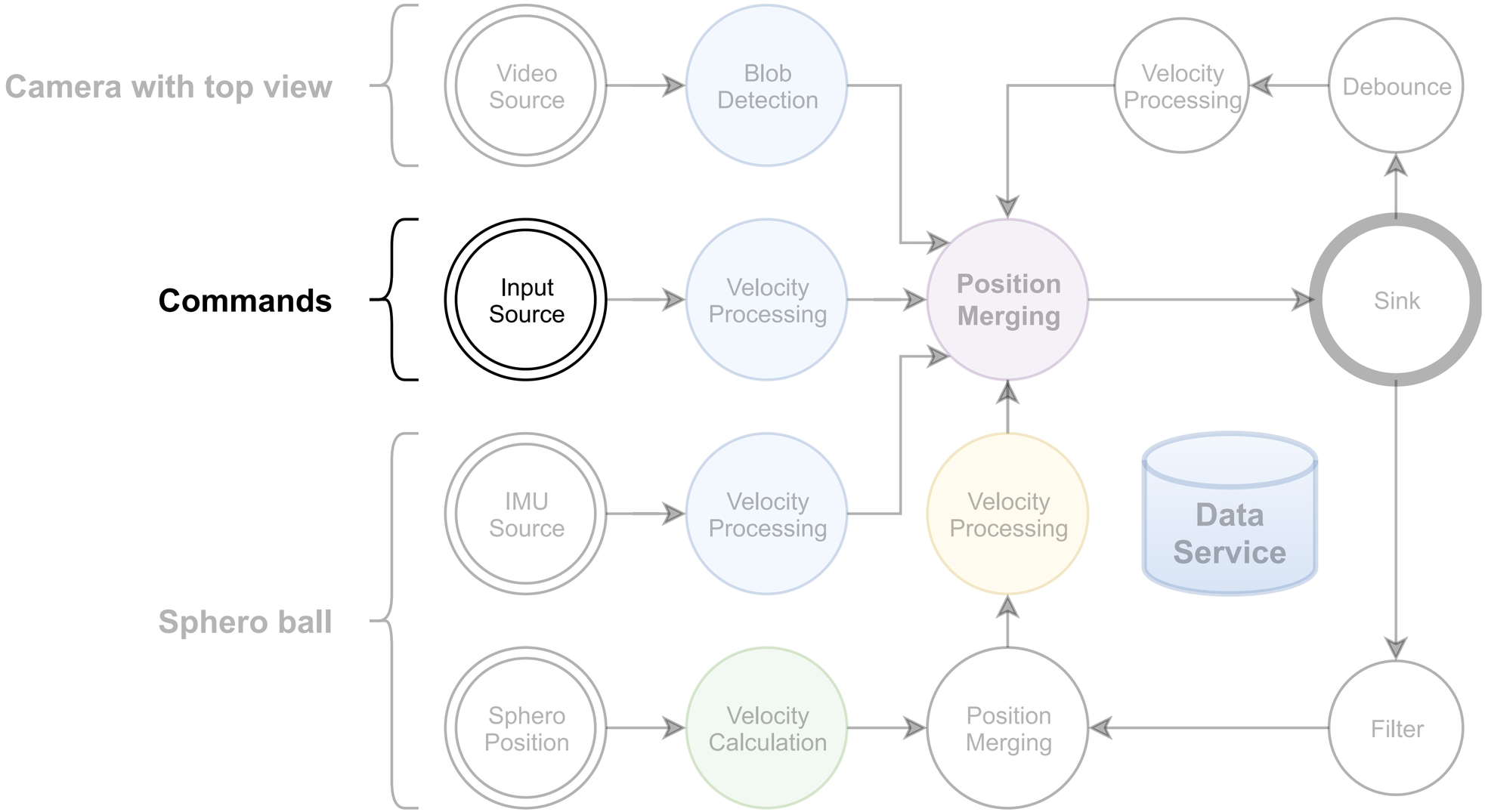
Example ...

OpenHPS



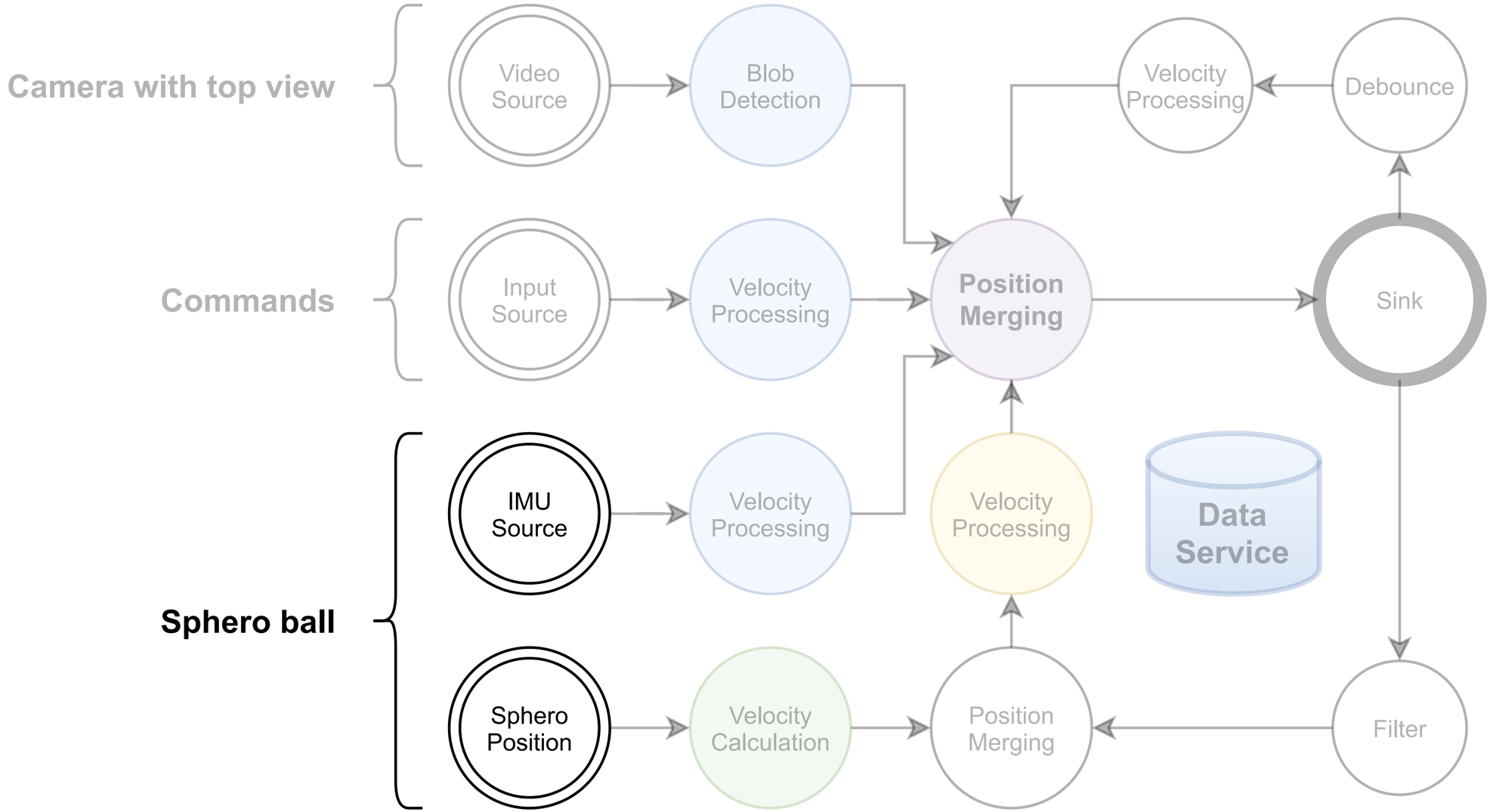
Example ...

OpenHPS



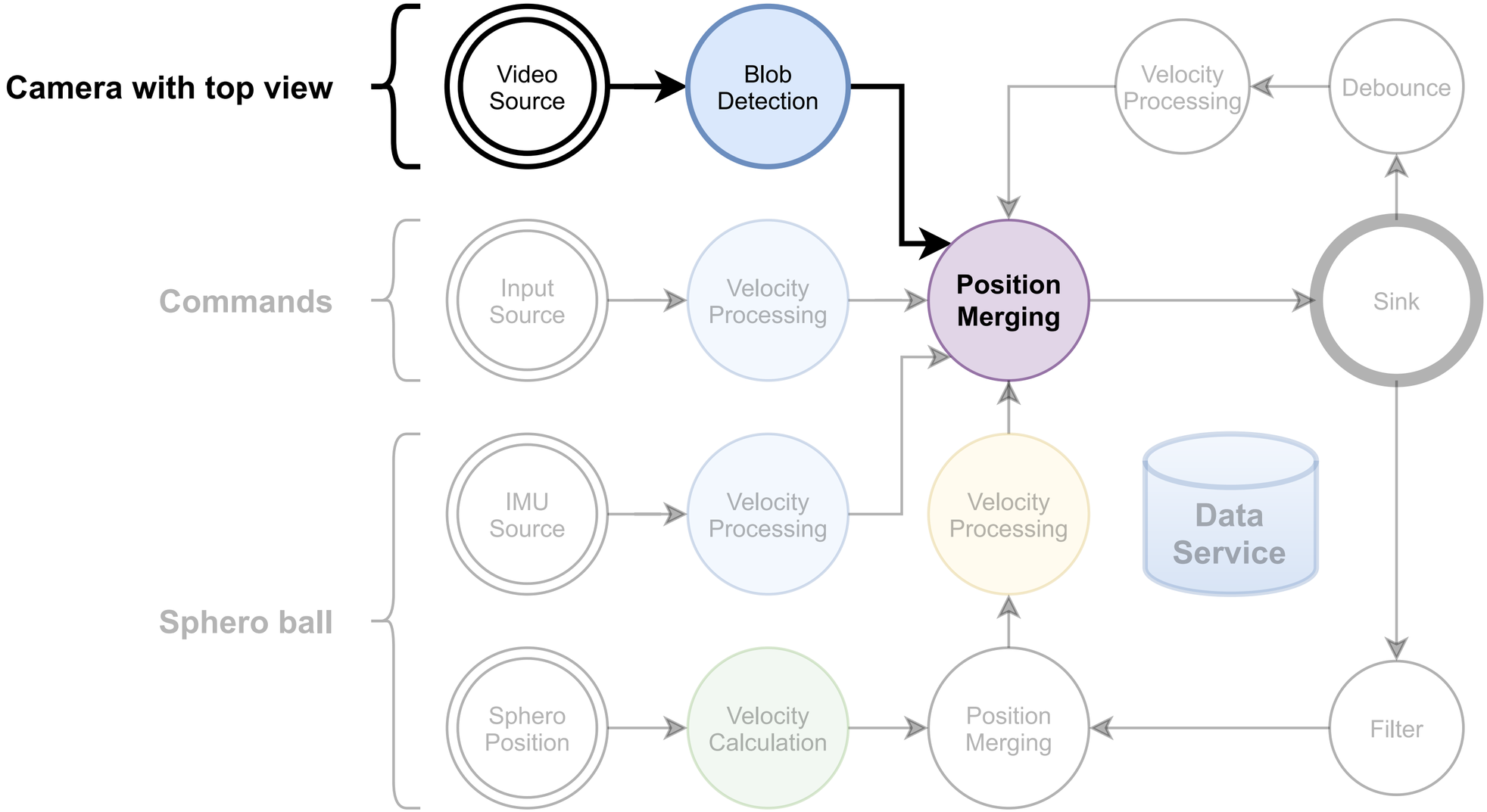
Example ...

OpenHPS



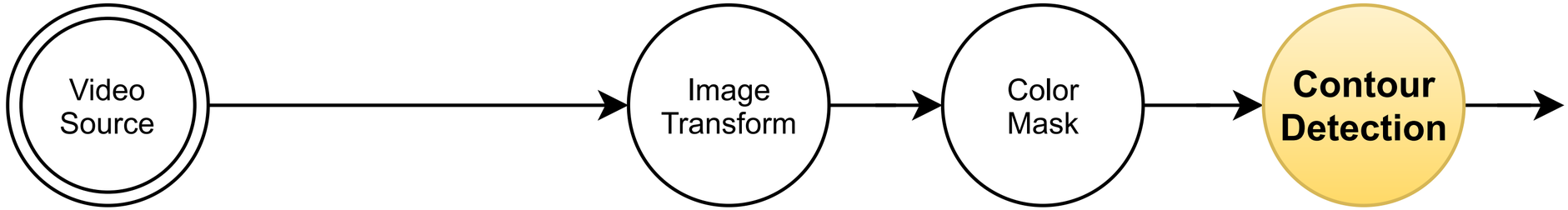
Example ...

OpenHPS

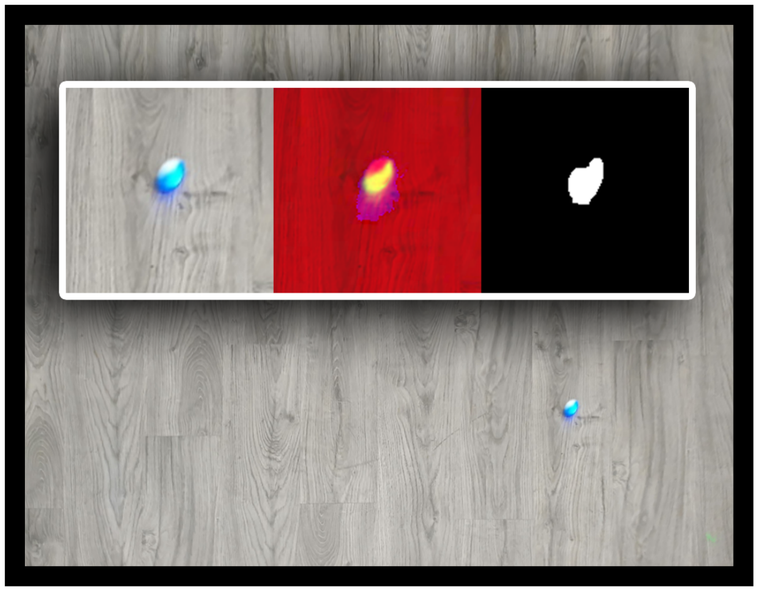


Example ...

OpenHPS



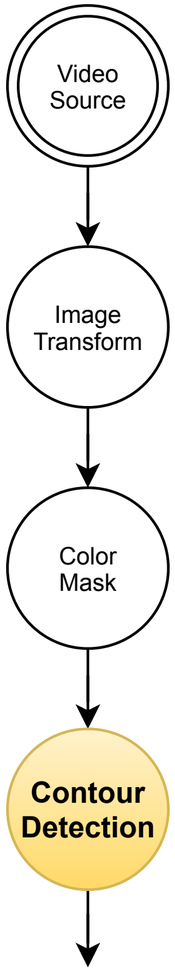
Original



Transformed & Mask

Example ...

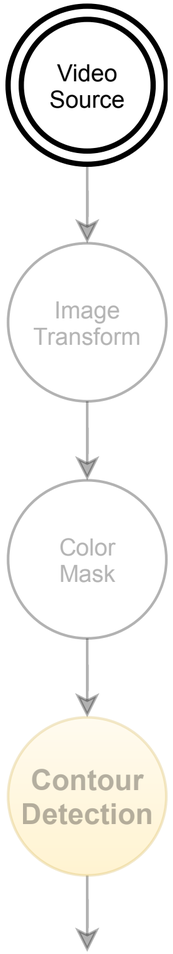
OpenHPS




```
GraphBuilder.create()
  .from(new VideoSource({
      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()) // Custom
  .to();
```

Example ...

OpenHPS

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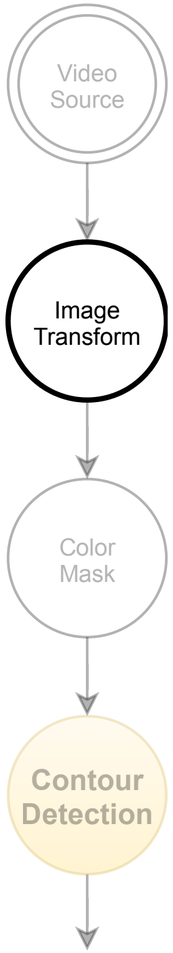
Example ...

OpenHPS

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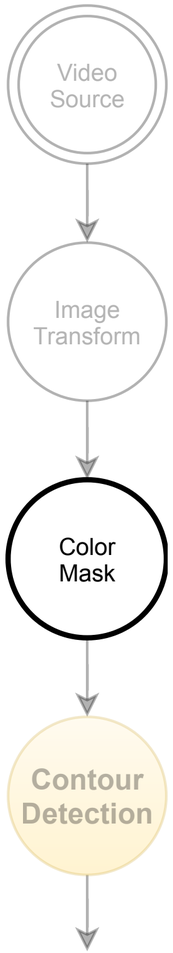
Example ...

OpenHPS

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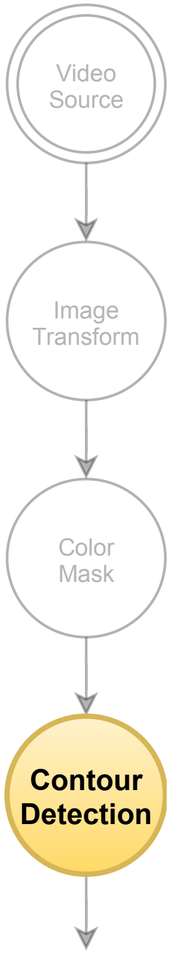
Example ...

OpenHPS

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  .to();
```

OpenCV: Contour Detection

OpenHPS

```
class ContourDetectionNode extends ProcessingNode<VideoFrame> {
    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 and select largest area as 'ball'
                contours = contours.sort((a, b) => a.area - b.area);
                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.addObject(new DataObject("ball").setPosition(position));
            }
            resolve(frame);
        });
    }
}
```

OpenCV: Contour Detection

OpenHPS

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OpenHPS

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                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; // Convert later
                position.accuracy = Math.sqrt(contours[0].area);
                frame.addObject(new DataObject("ball").setPosition(position));
            }
            resolve(frame);
        });
    }
}
```
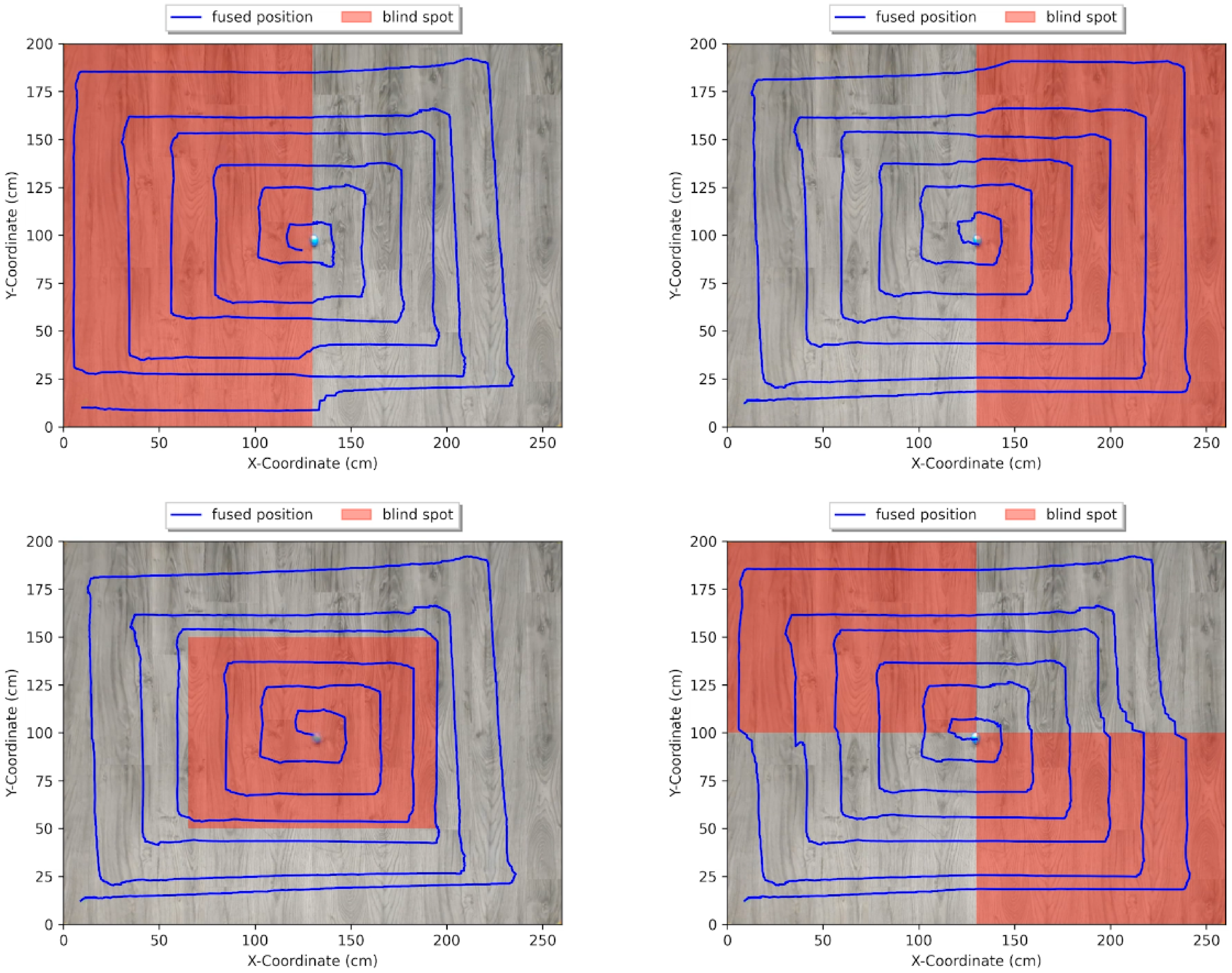

OpenHPS



fused position
blind spot
200
175
150
125
100
75
50
25
0
0
50
100
150
200
250
Y-Coordinate (cm)
X-Coordinate (cm)
fused position
blind spot
Y-Coordinate (cm)
X-Coordinate (cm)
fused position
blind spot
Y-Coordinate (cm)
X-Coordinate (cm)
fused position
blind spot
Y-Coordinate (cm)
X-Coordinate (cm)

Contributing and Future Work

OpenHPS

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

Resources and Links

OpenHPS

https://openhps.org

https://github.com/OpenHPS

https://npmjs.com/org/openhps

https://twitter.com/OpenHPS

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<mvdewync@vub.be>