Rapid Prototyping of a Positioning System Using the OpenHPS Framework

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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**

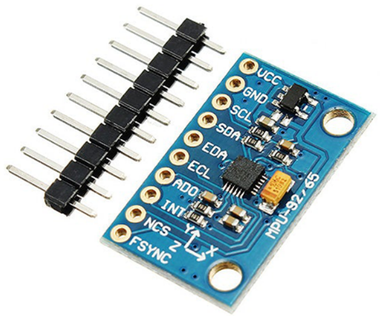
Geospatial mapping of an environment

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

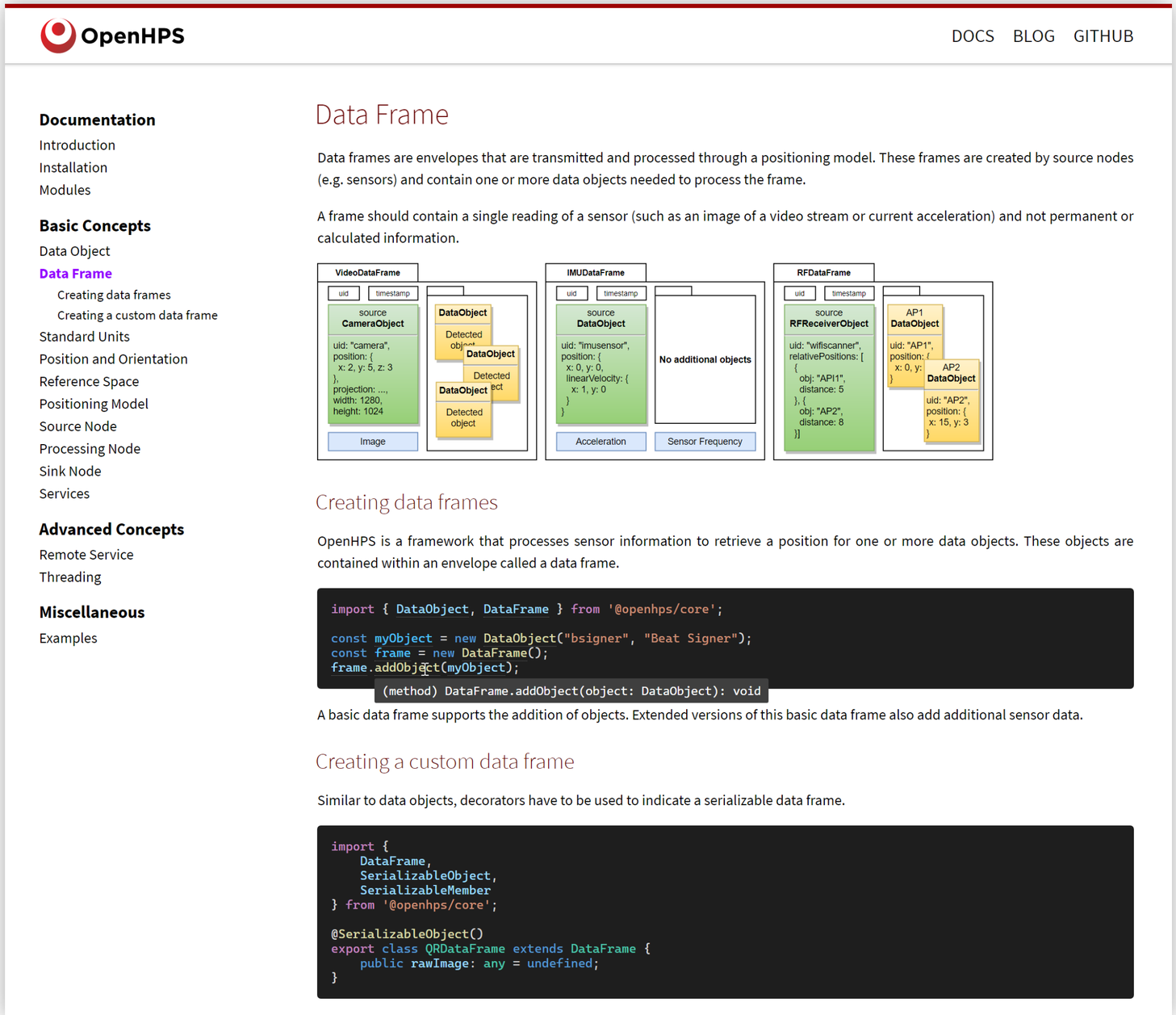
OpenHPS

- 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



OpenHPS

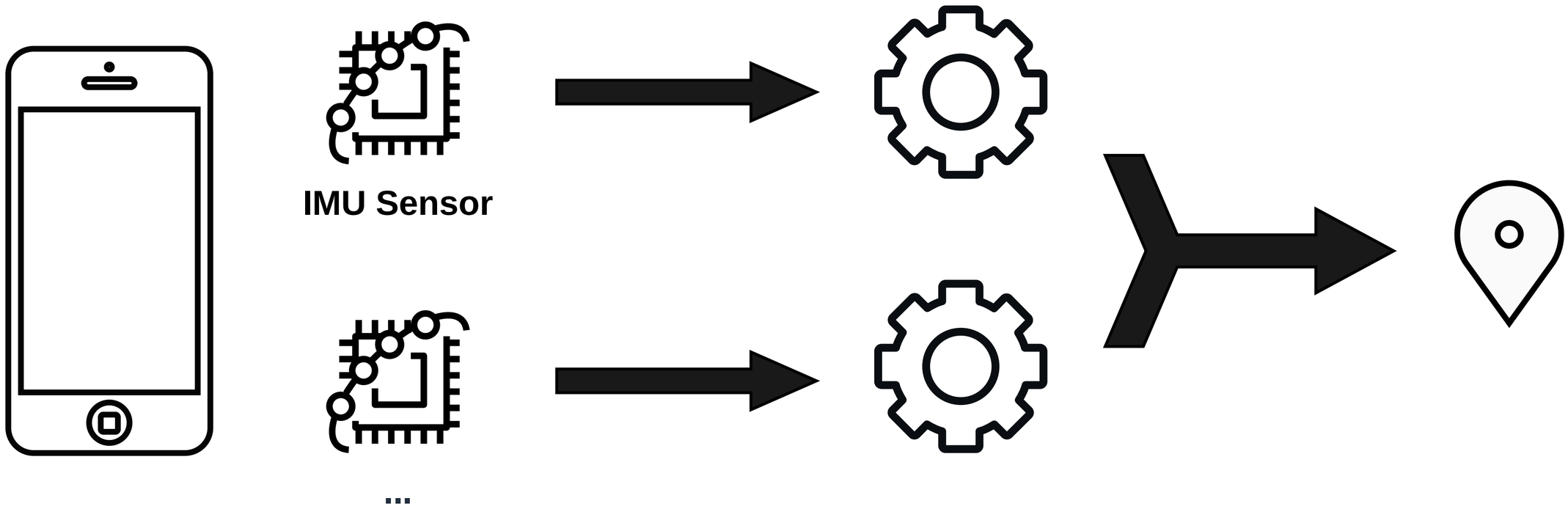
OpenHPS

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

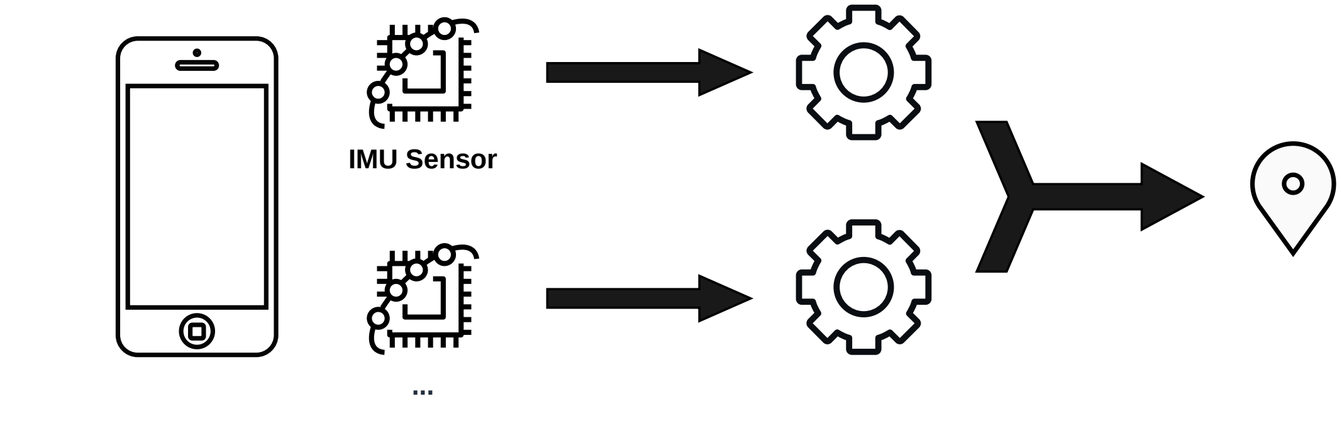
Process Network Design

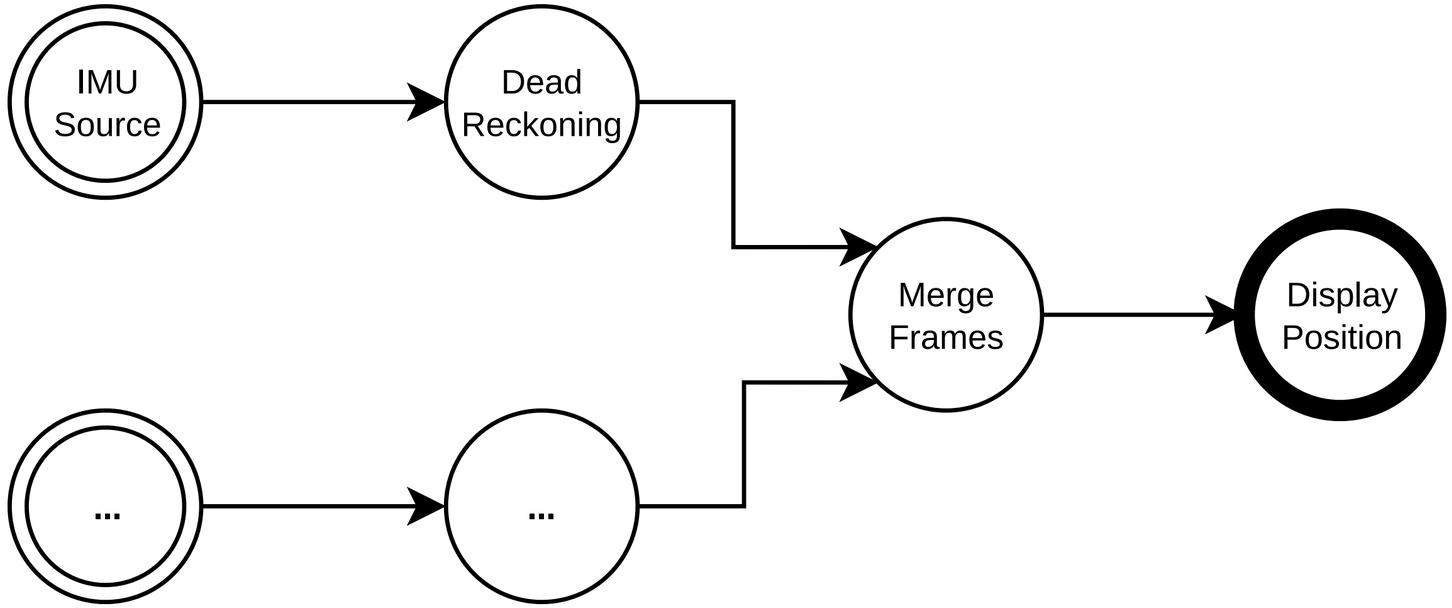
OpenHPS



Process Network Design ...

OpenHPS





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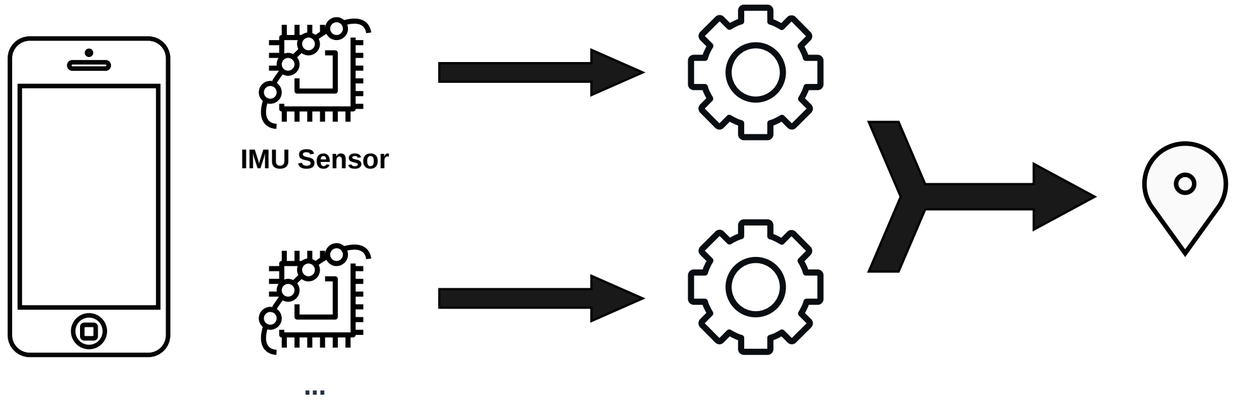

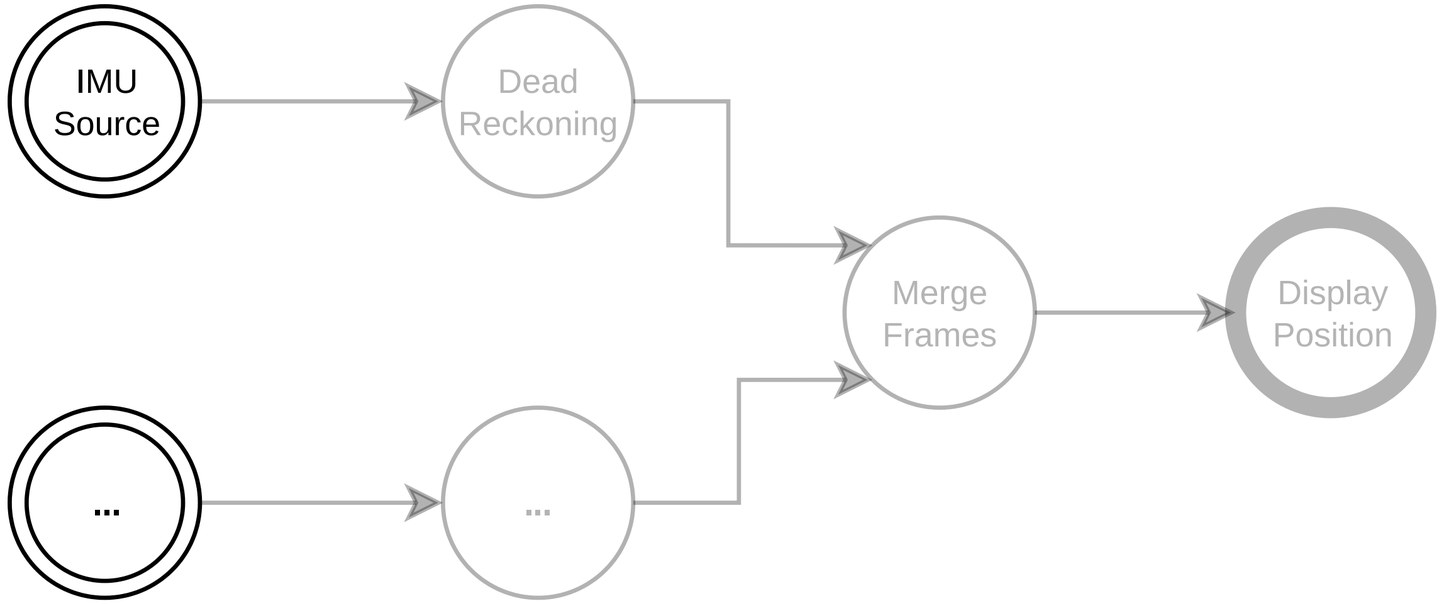

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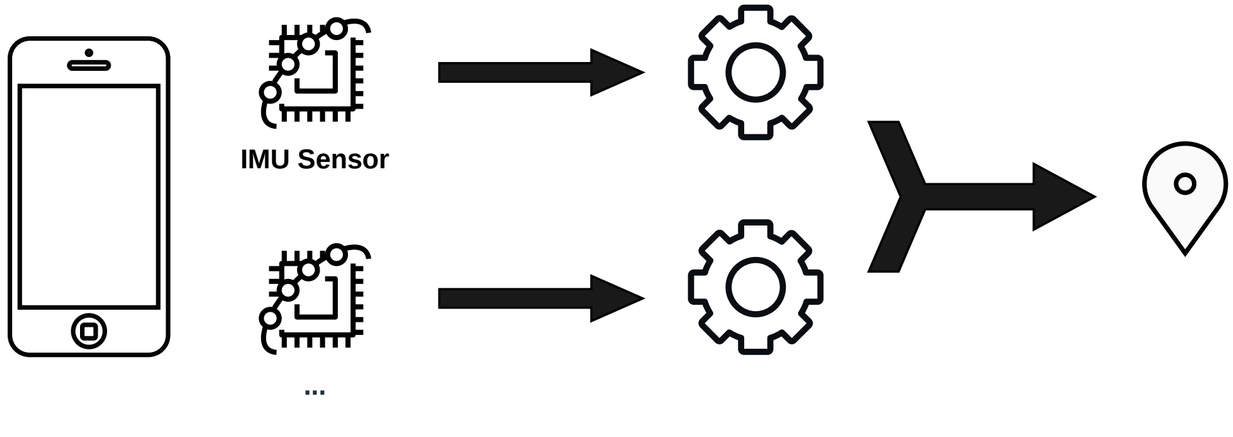

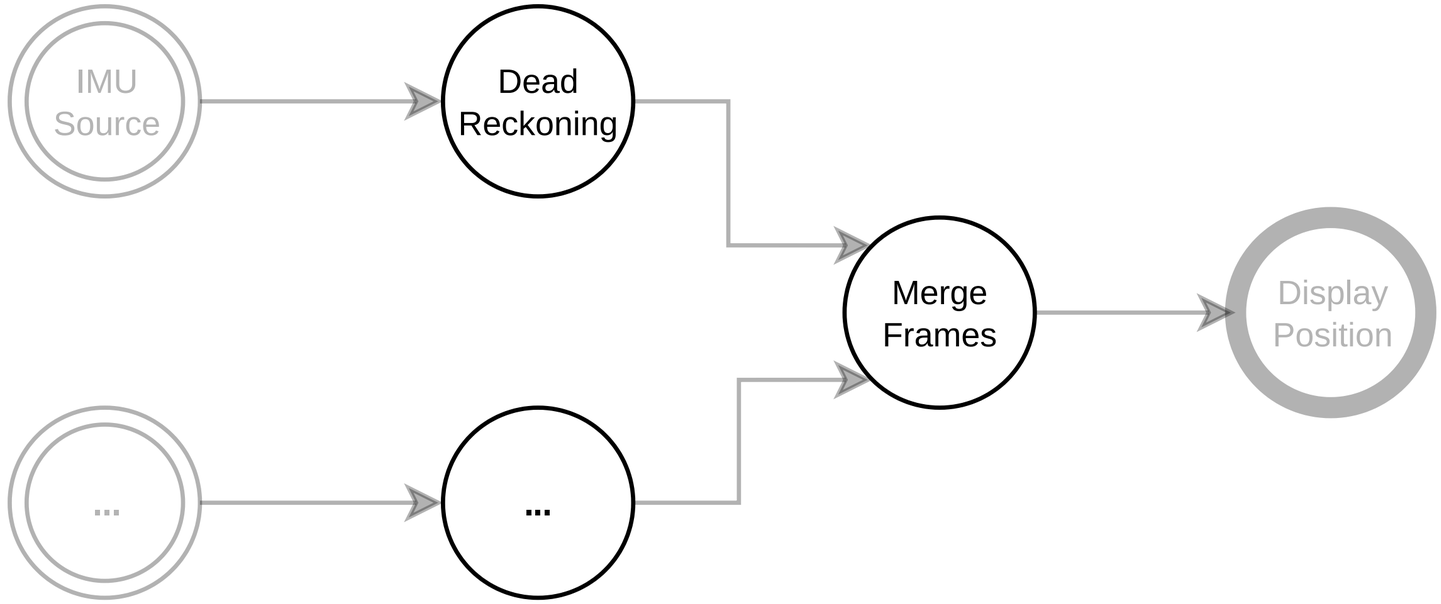

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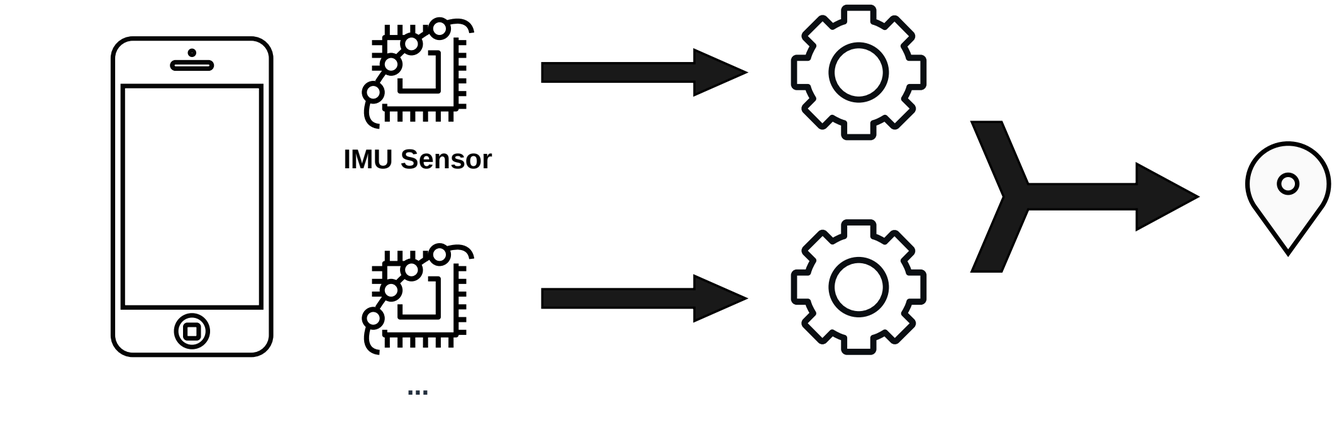
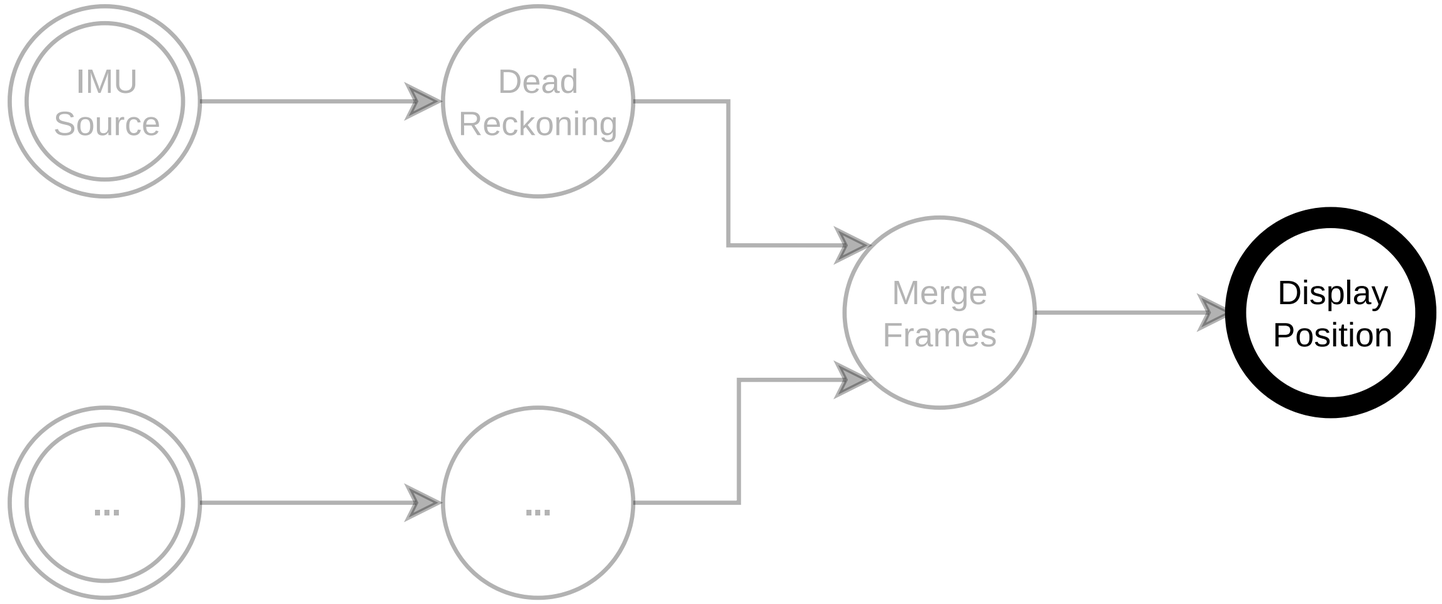
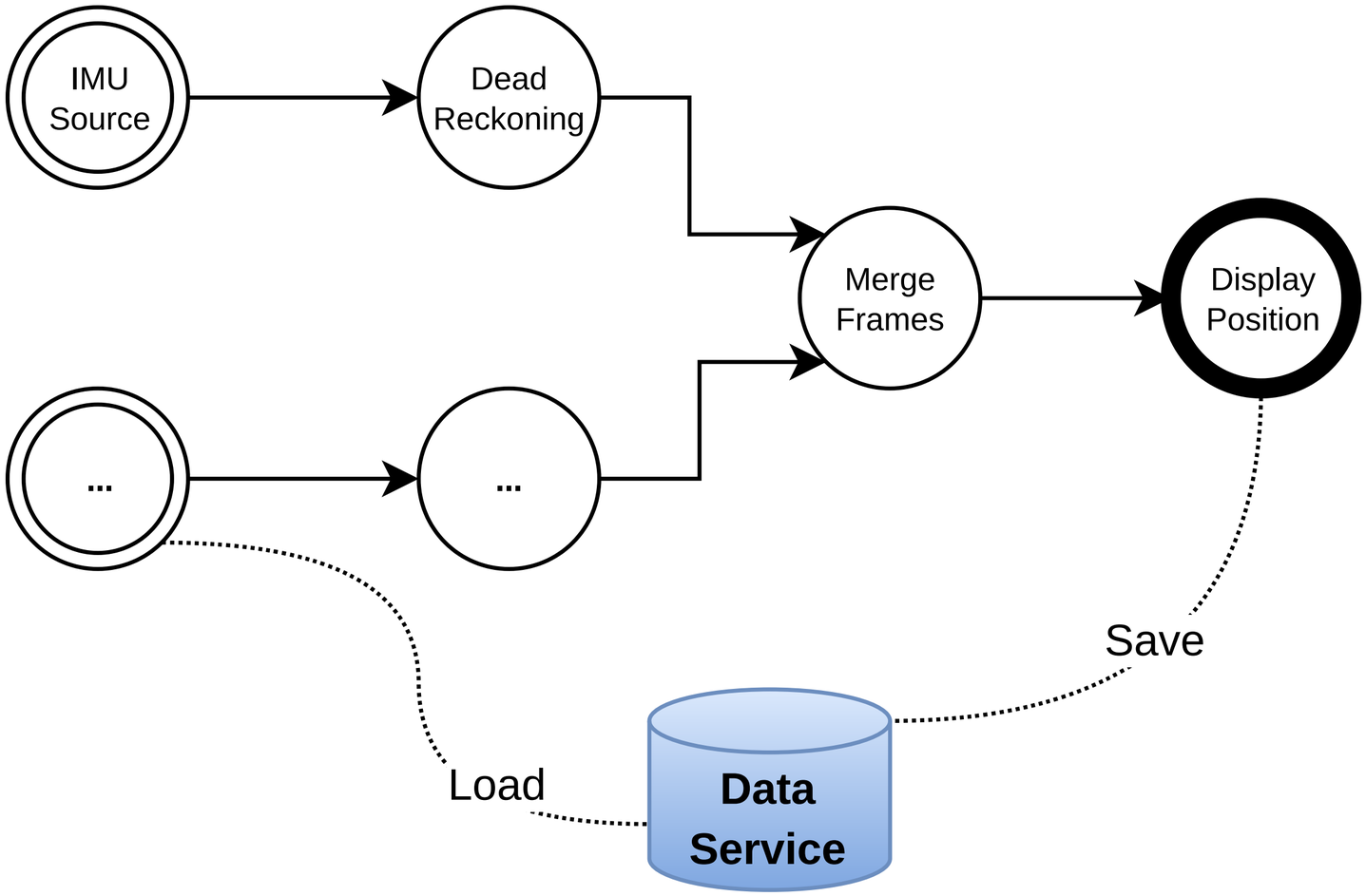




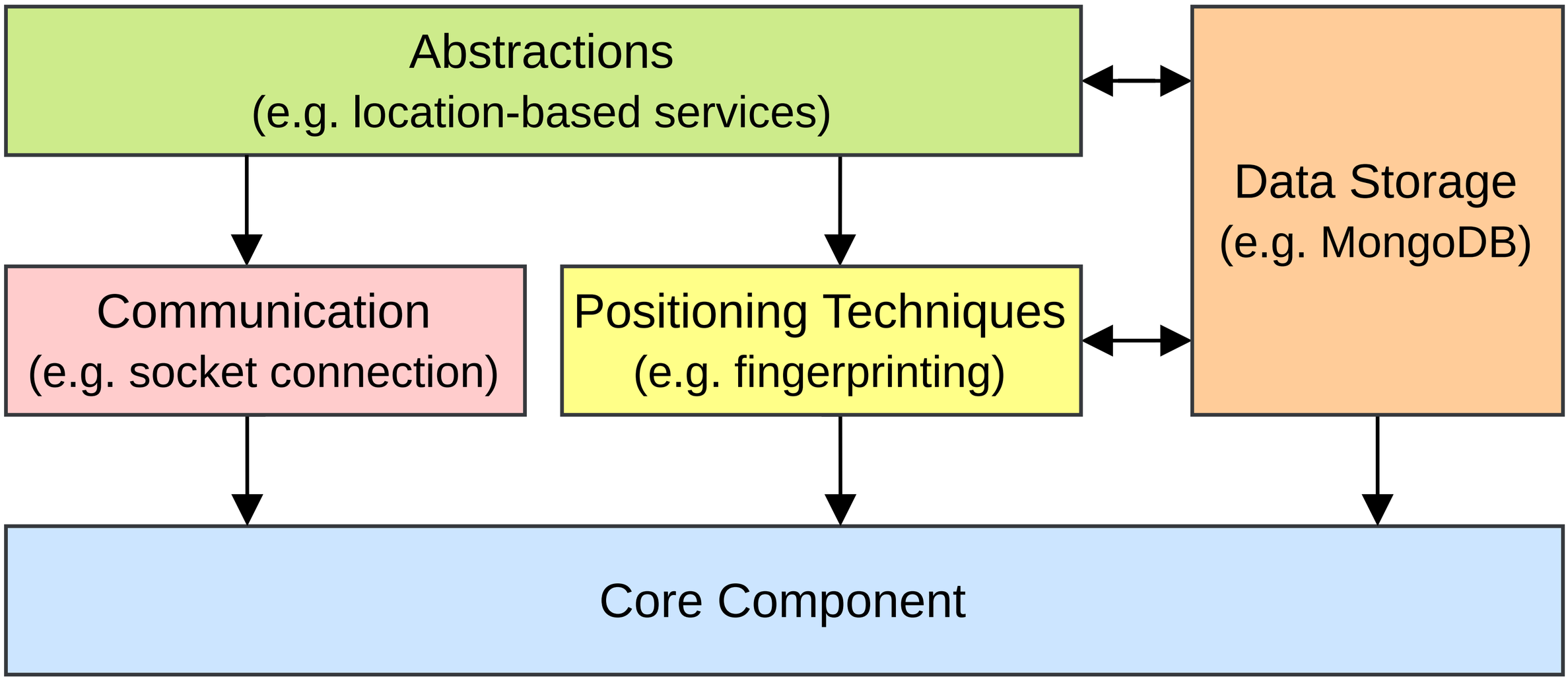
Process Network Design ...

OpenHPS



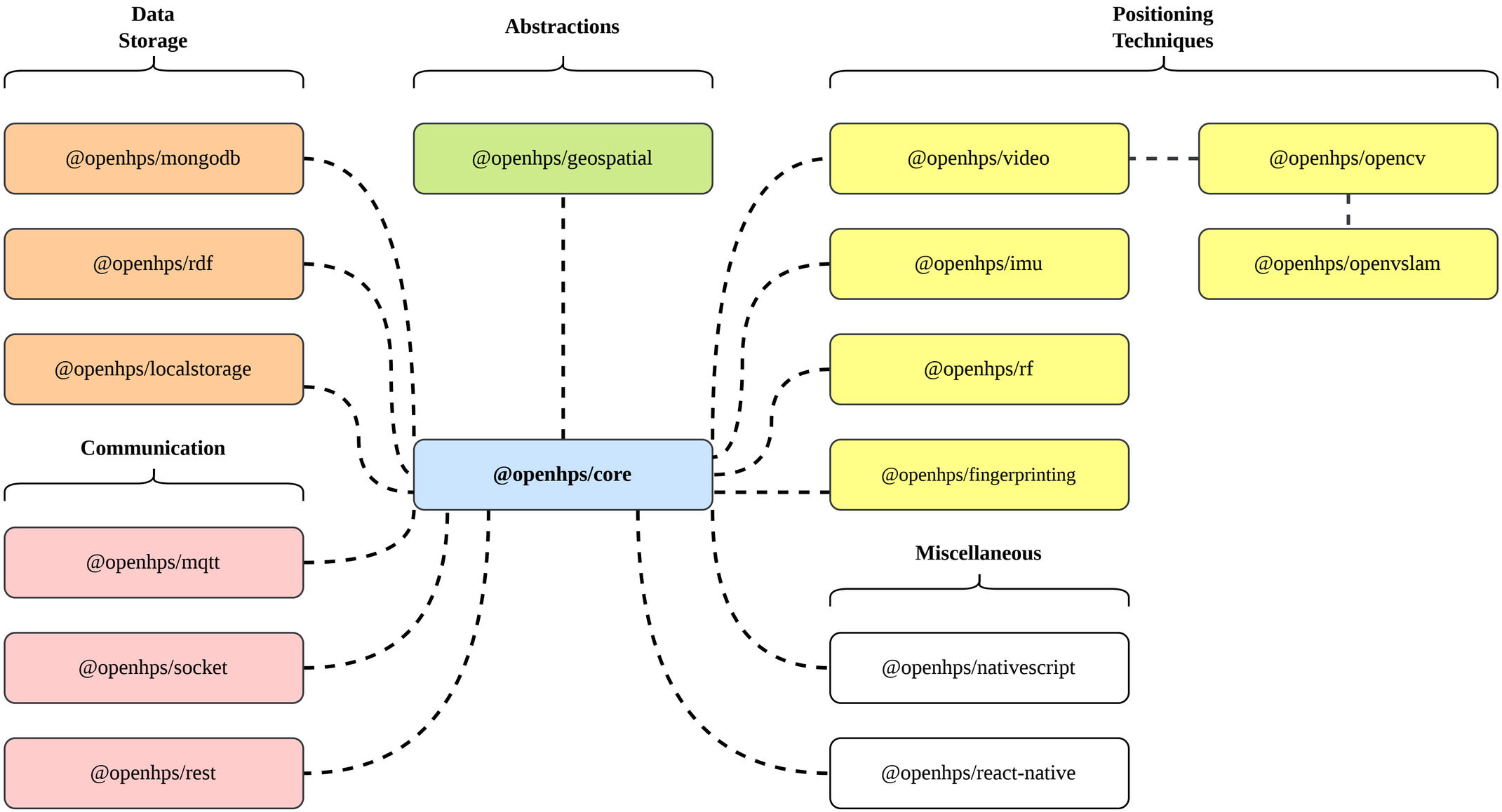
Modularity

OpenHPS



Modularity ...

OpenHPS



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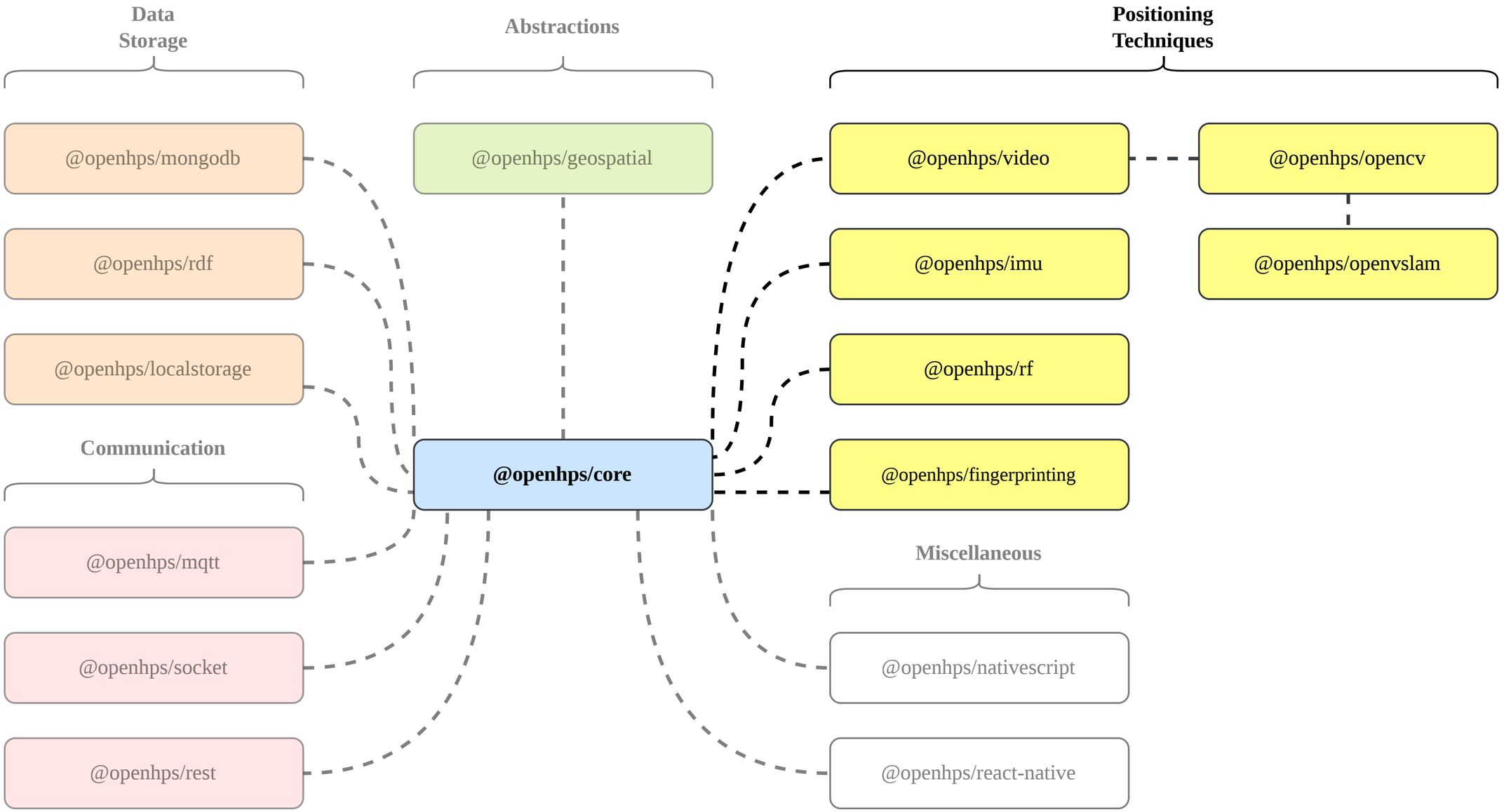

Modularity ...

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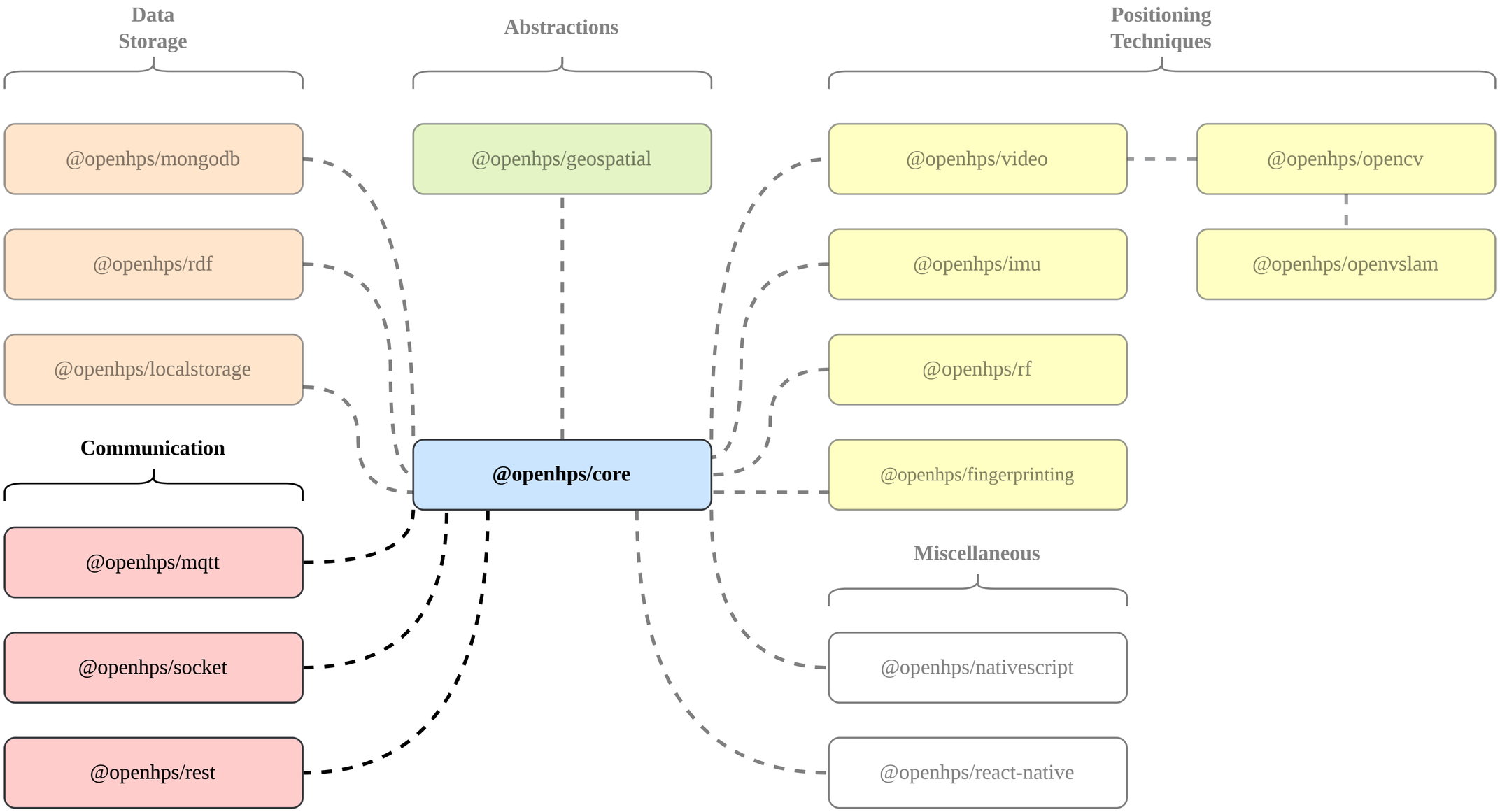

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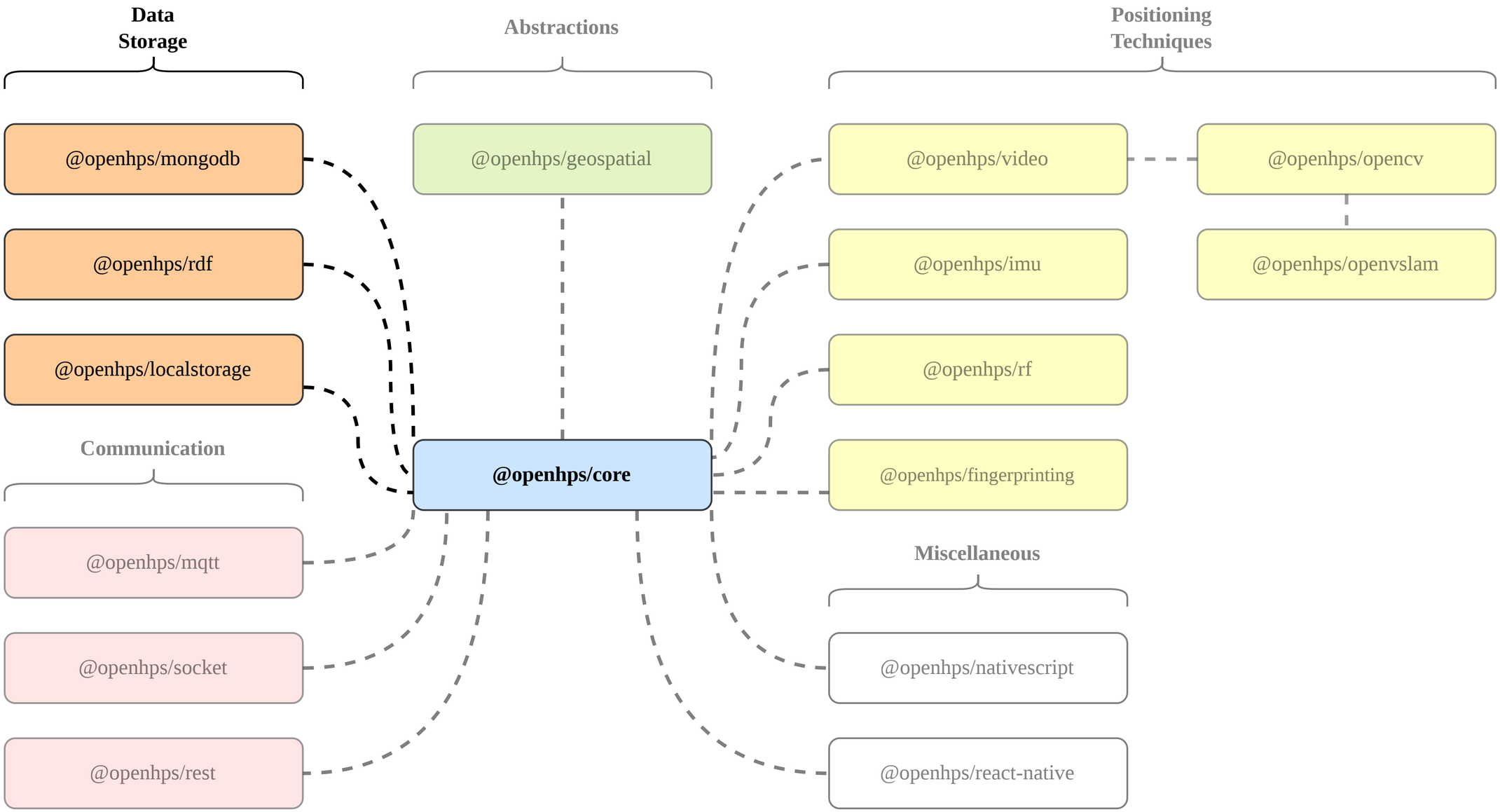

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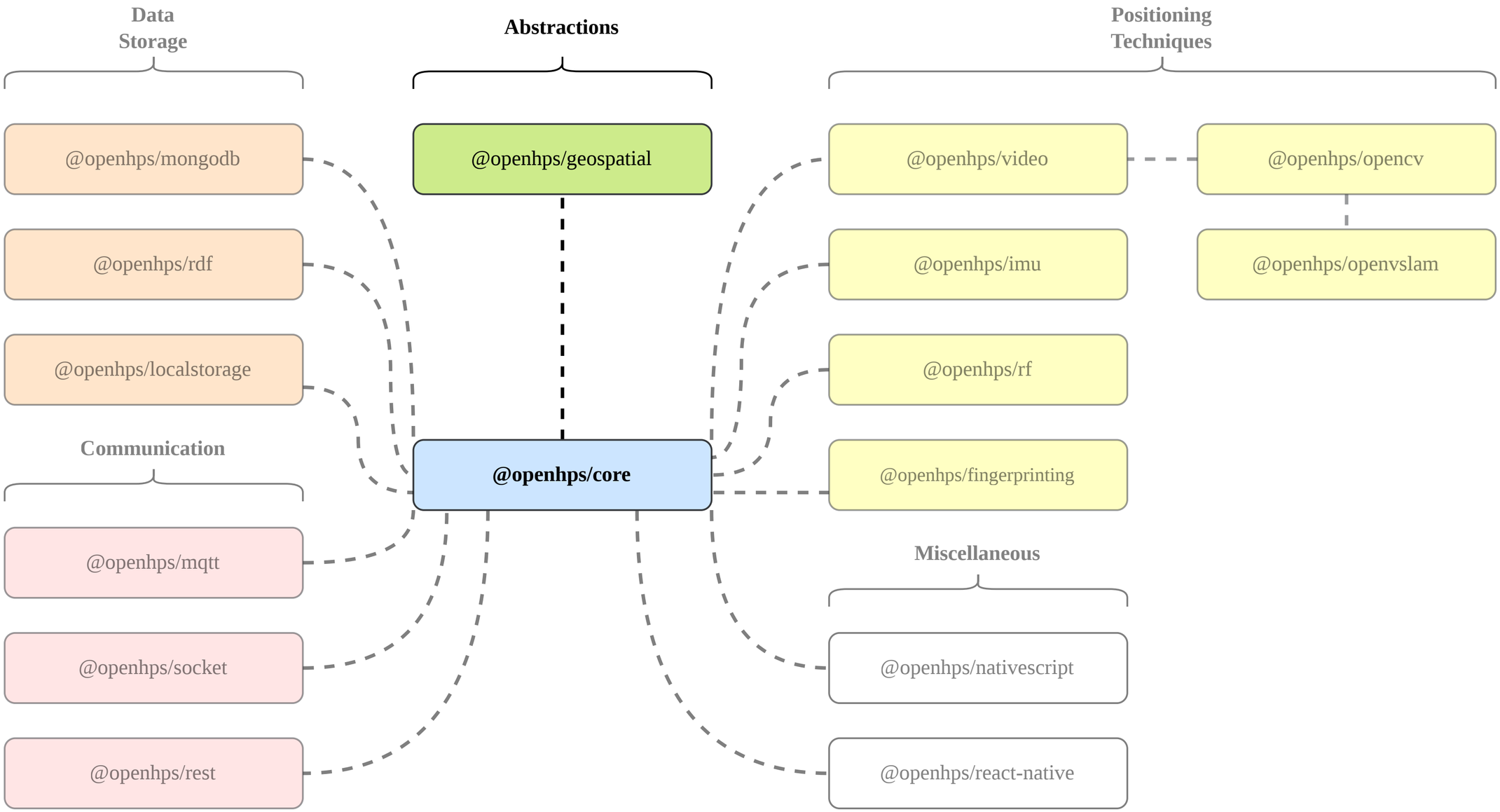
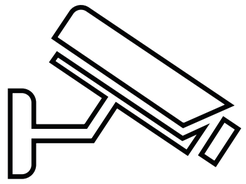
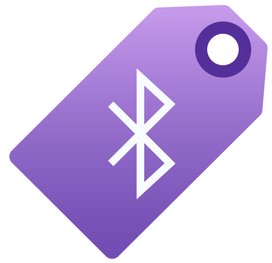
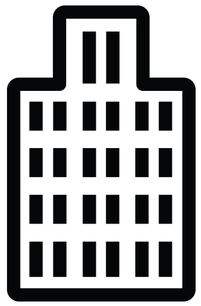


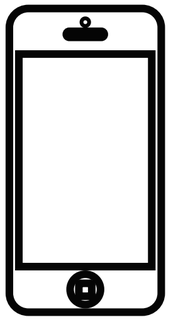
Data Processing

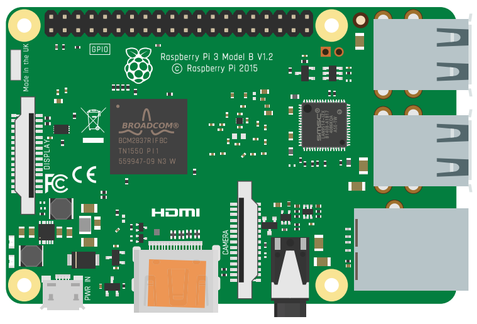
OpenHPS

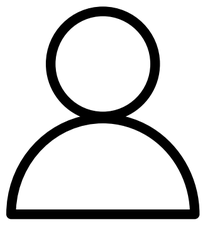


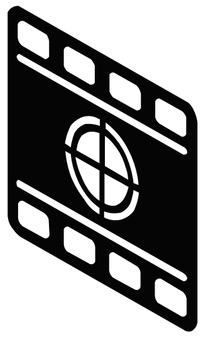






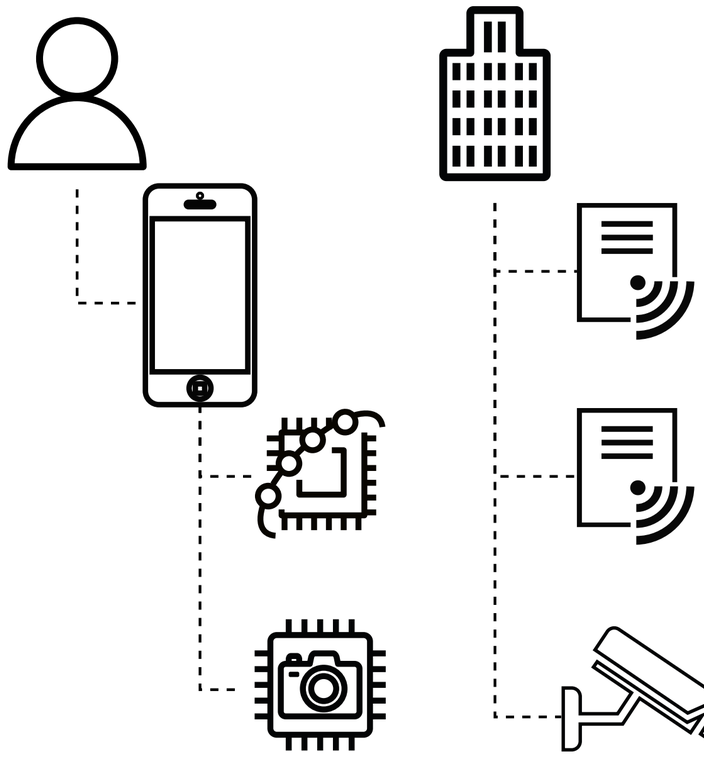






DataObject

OpenHPS



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

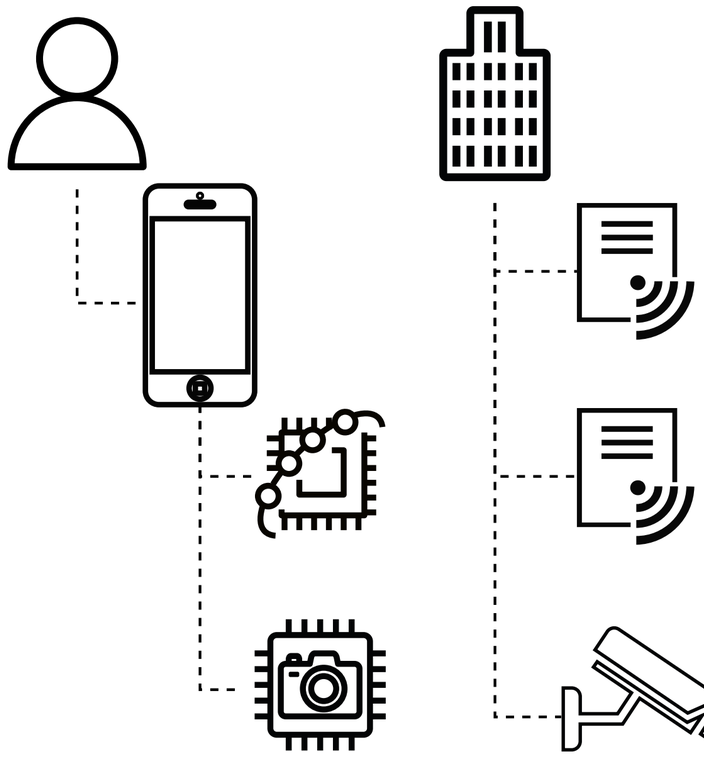
// Phone belonging to the person
const phone = new DataObject()
phone.displayName = "Maxim's Phone";
phone.setParent(me);

// 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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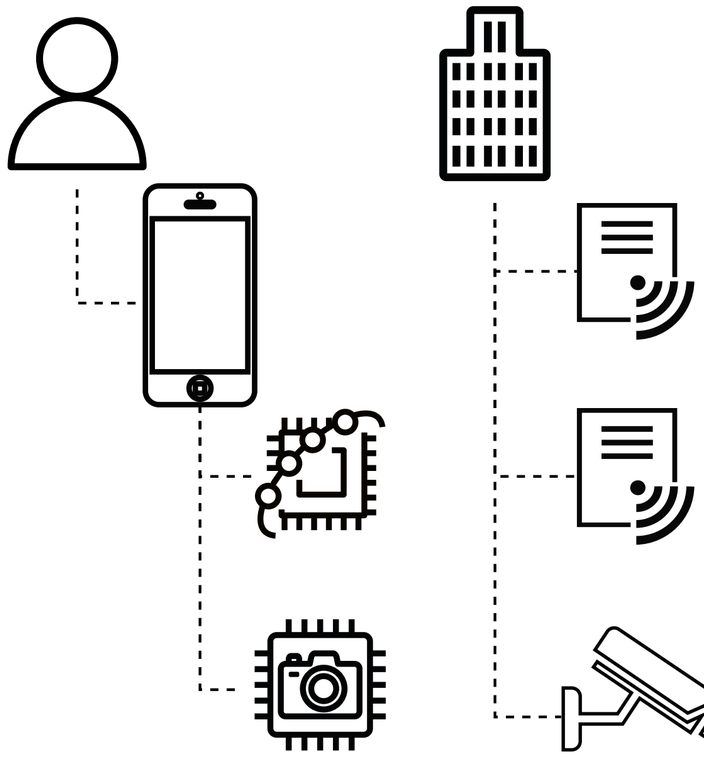

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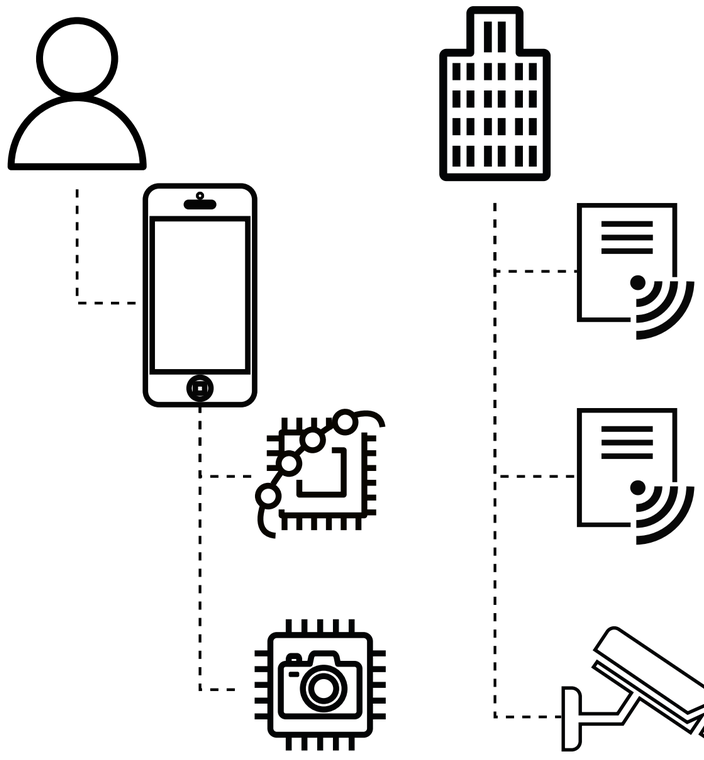

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camera.height = 1024;
camera.fps = 30;
camera.setPosition(/* ... */);
```

Absolute and Relative Positions

OpenHPS

Absolute

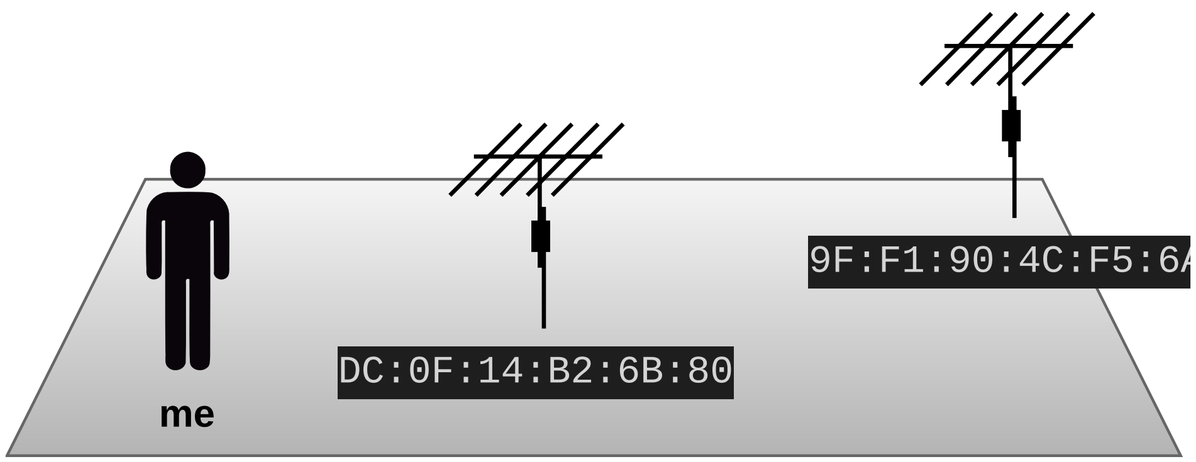
- 2D, 3D, geographical, ...
- Within a reference space

Relative

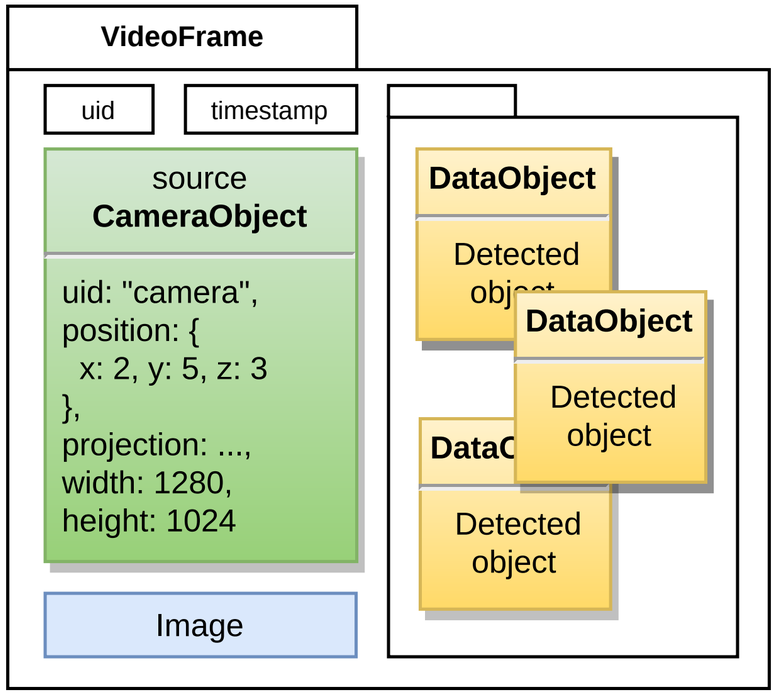
- Distance, angle, velocity, ...
- Relative to another *object*

```
// 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
));
```



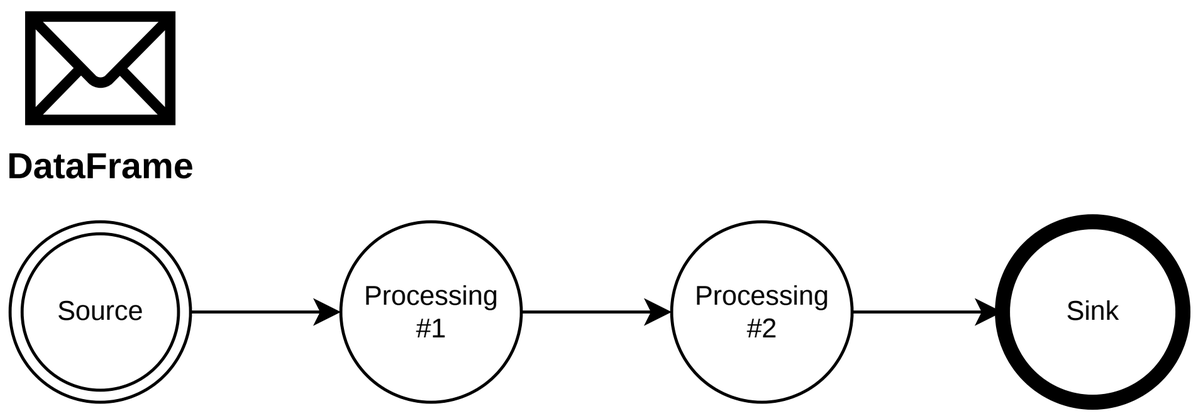
DataFrame




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

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

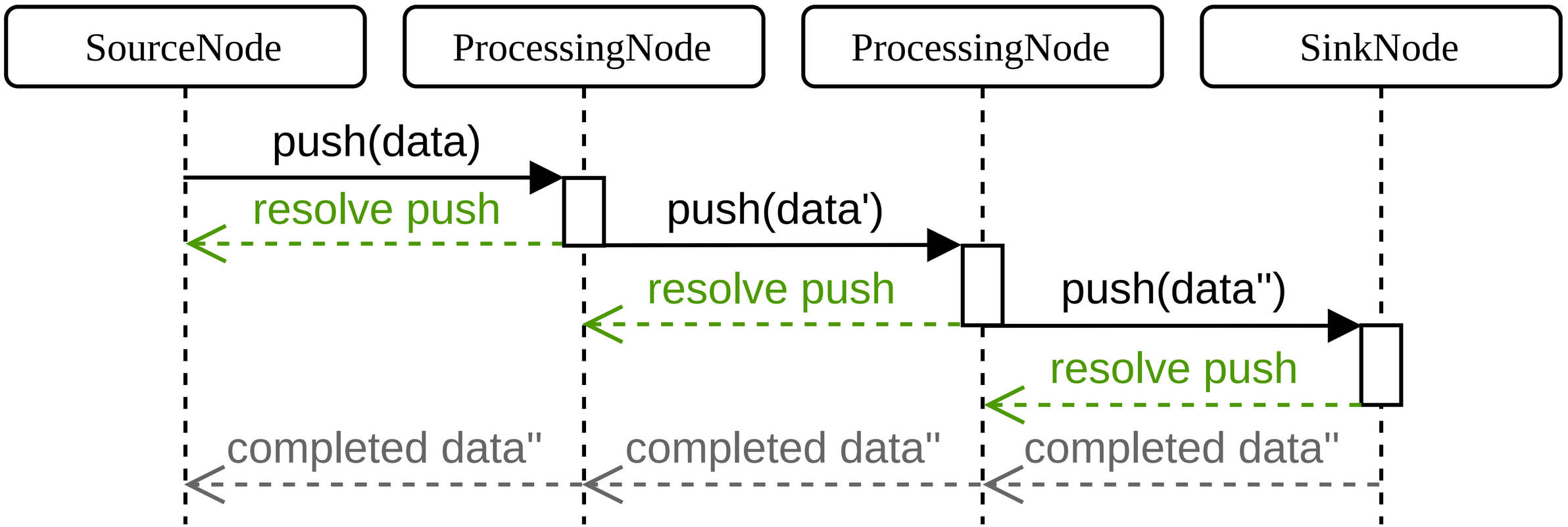
// Add detected objects to frame
frame.addObject(/* ... */);
frame.addObject(/* ... */);
frame.addObject(/* ... */);
```



DataFrame ...

OpenHPS

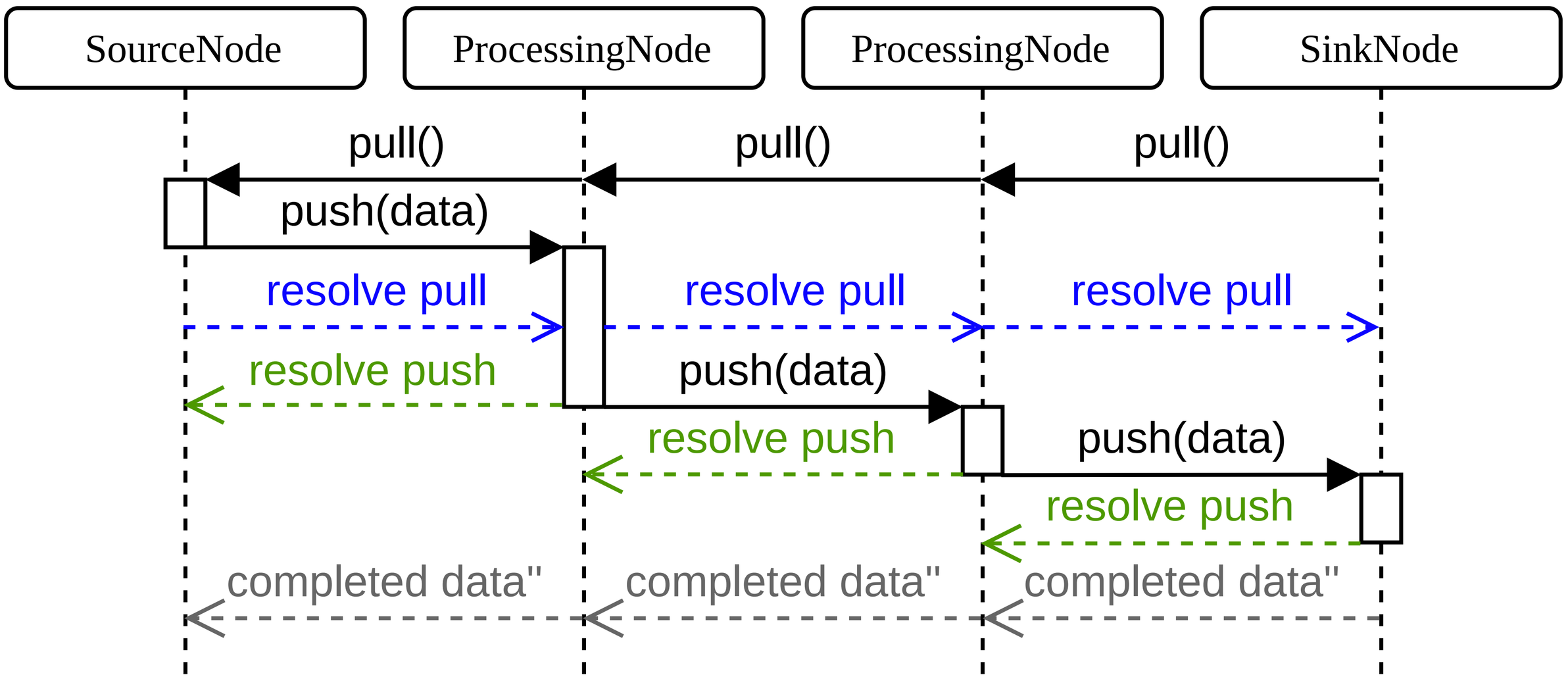
Pushing Data



DataFrame ...

OpenHPS

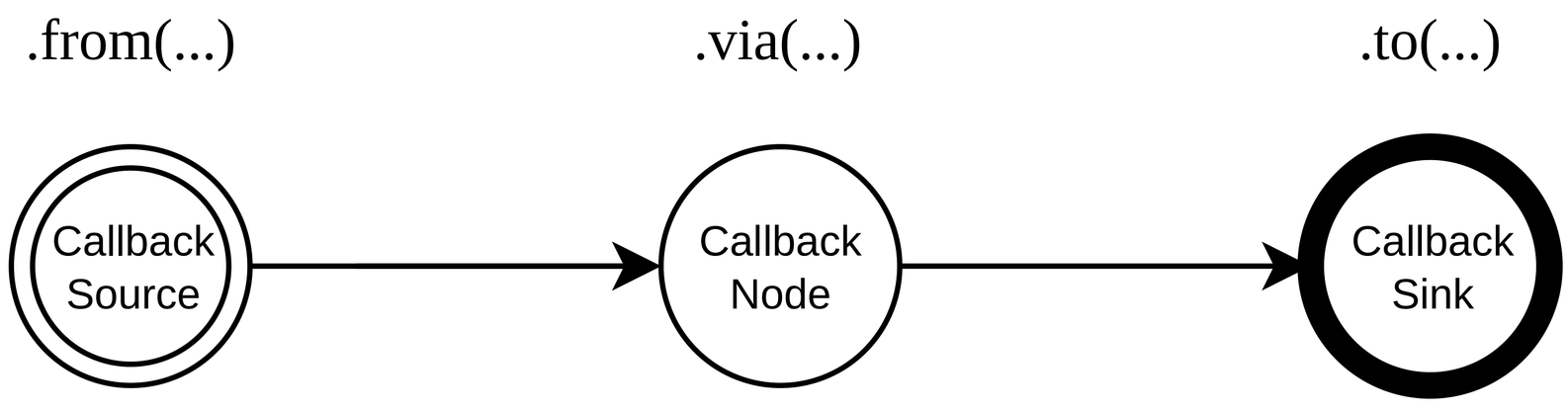
Pulling Data



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) => { /* ... */ });
```

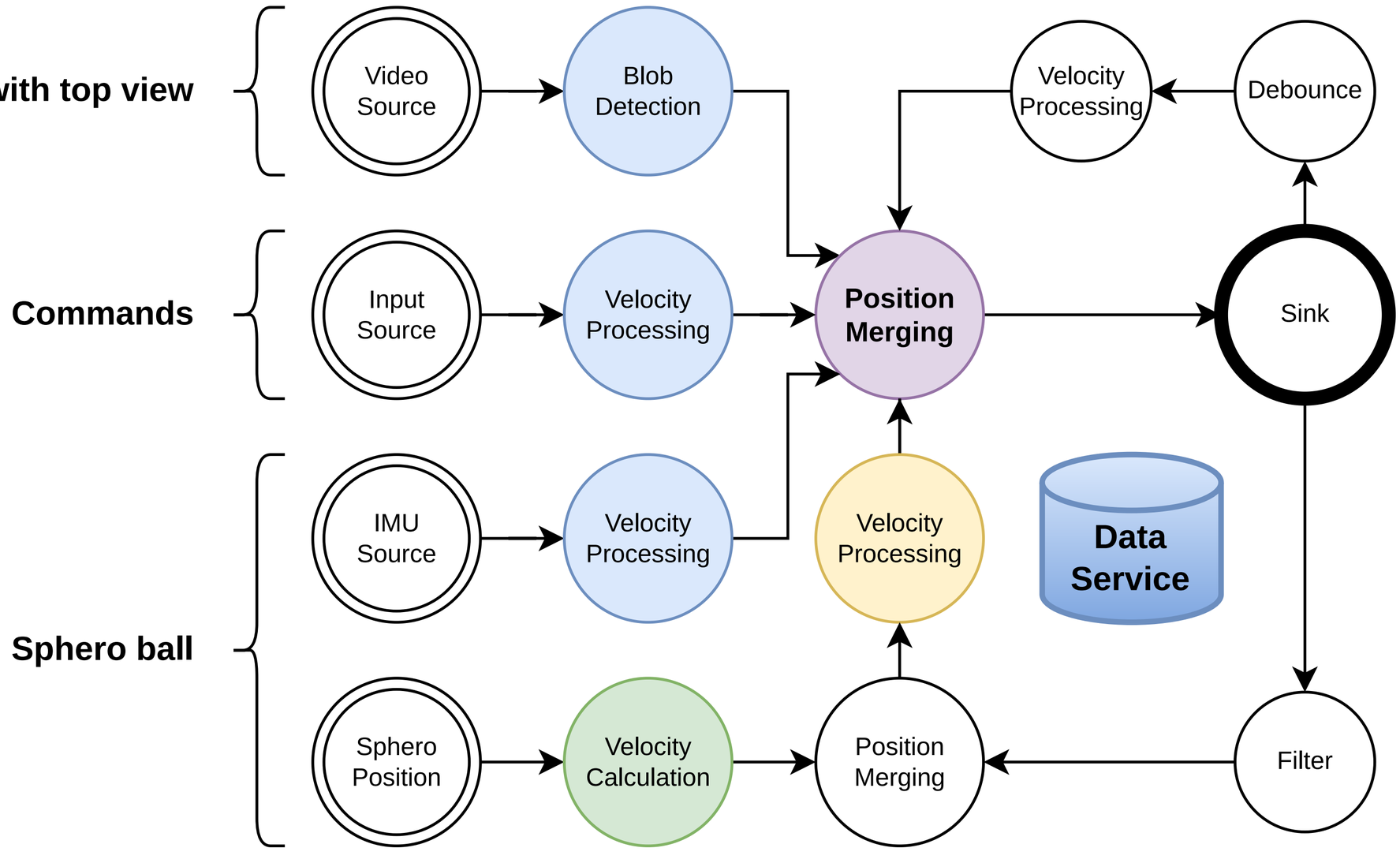


Example

OpenHPS

Example ...

OpenHPS



Example ...

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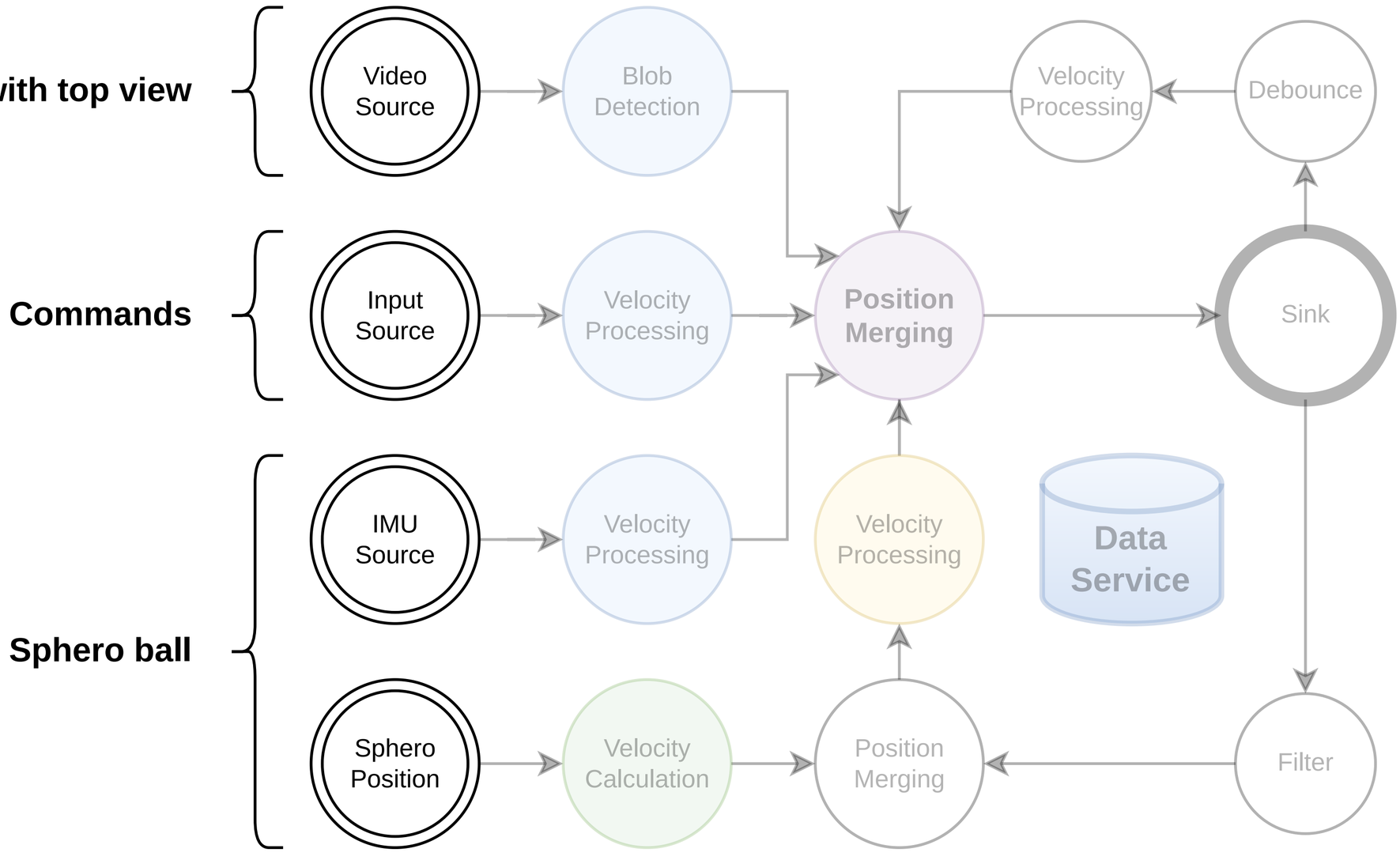
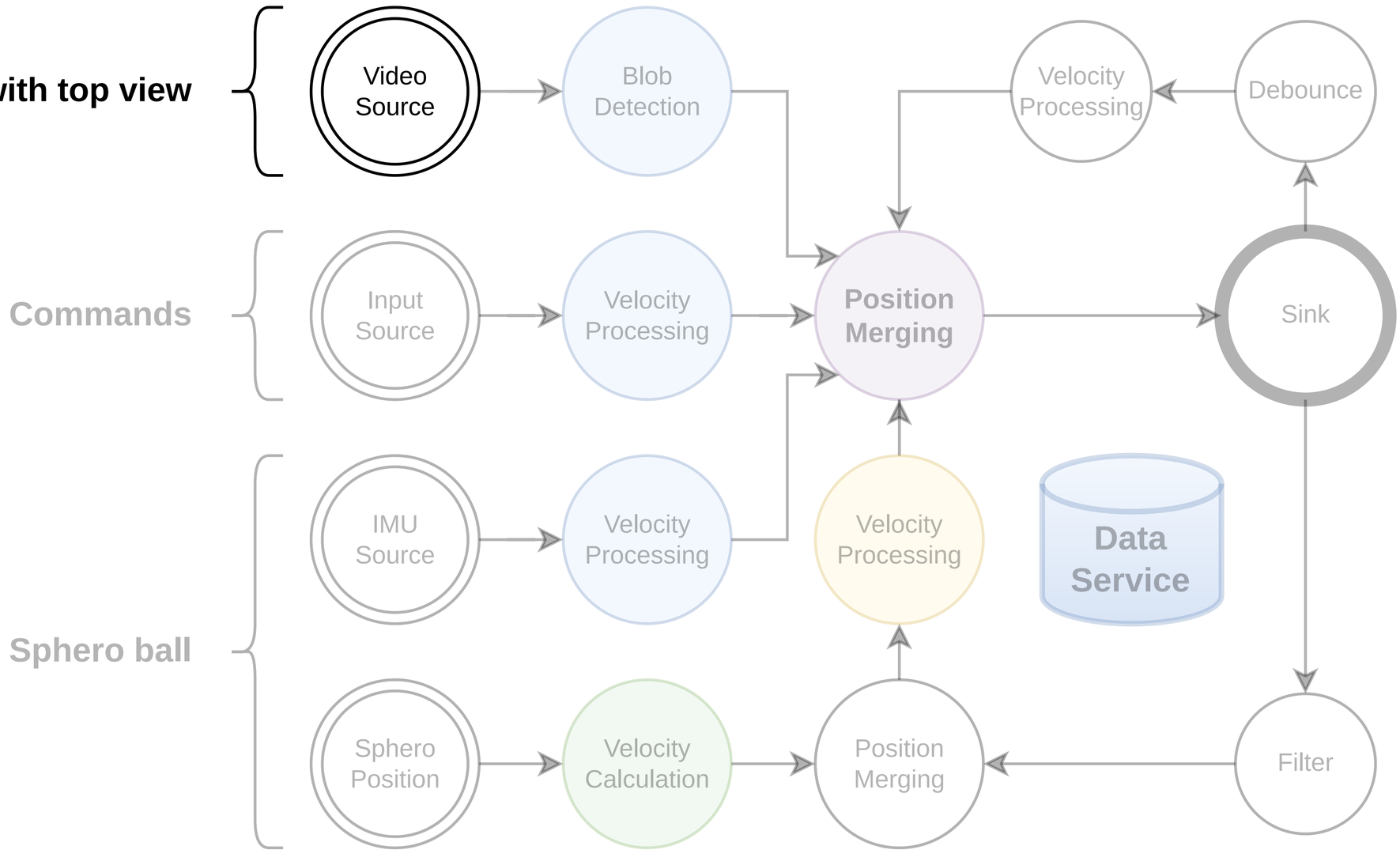


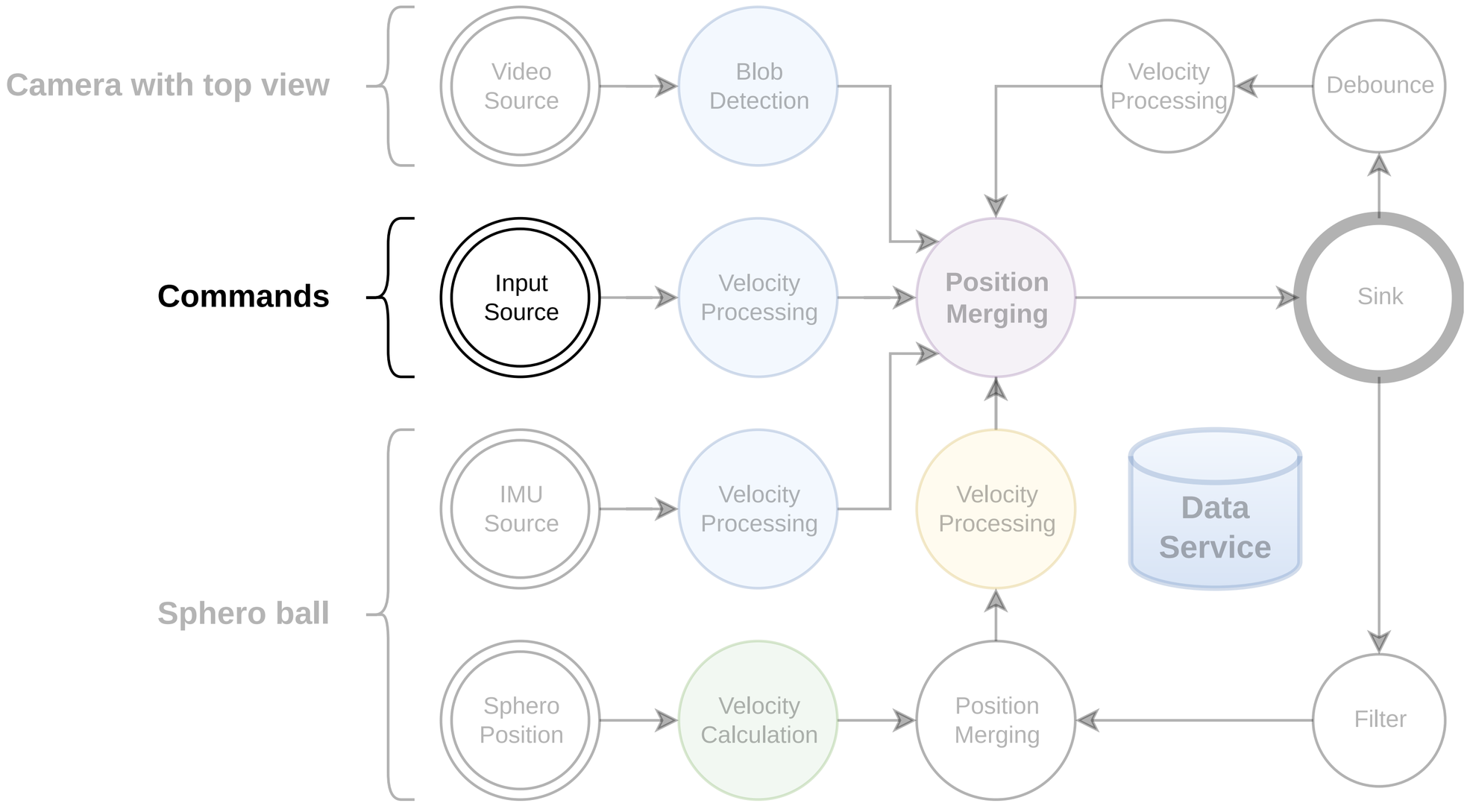
Example ...

OpenHPS



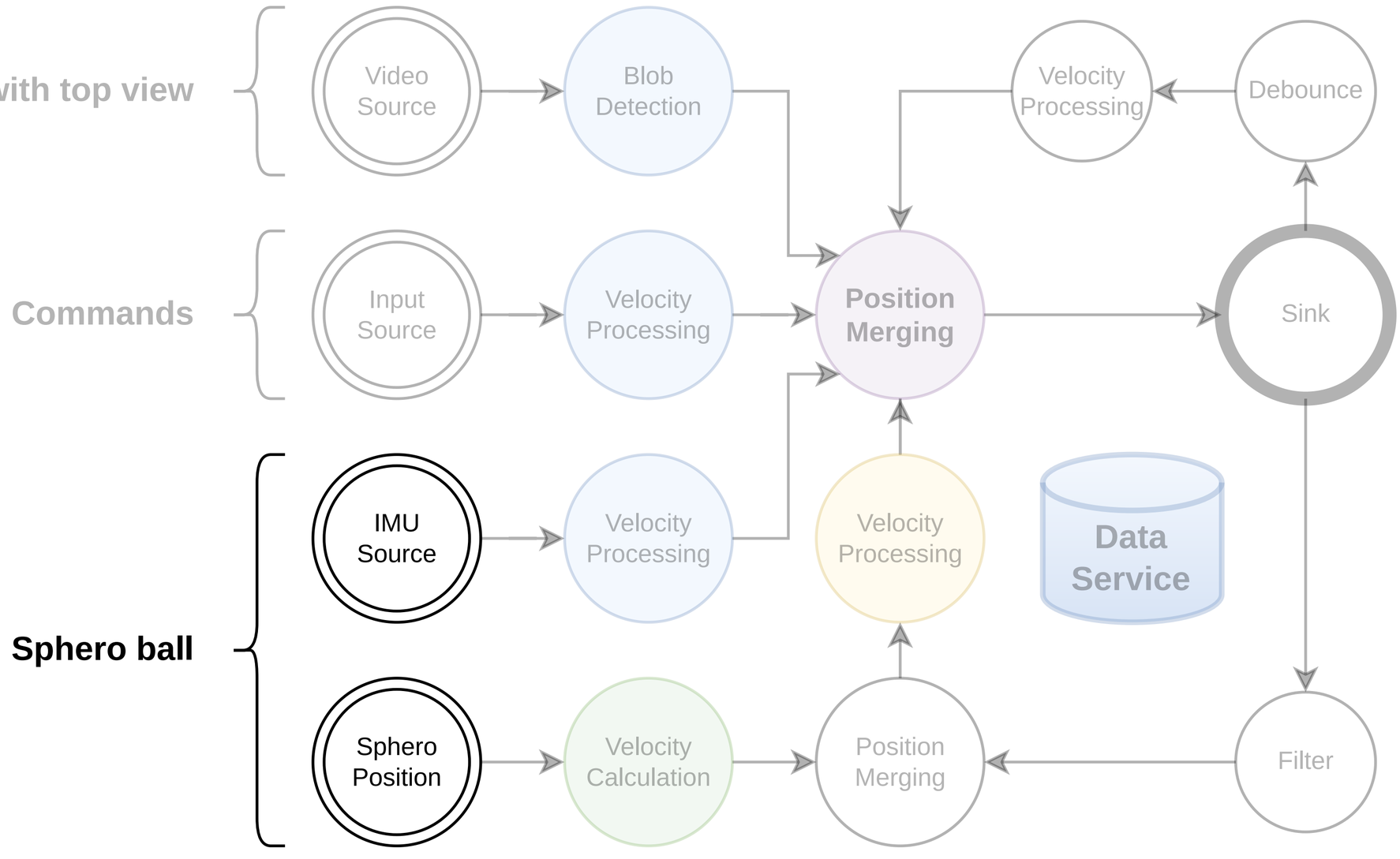
Example ...

OpenHPS



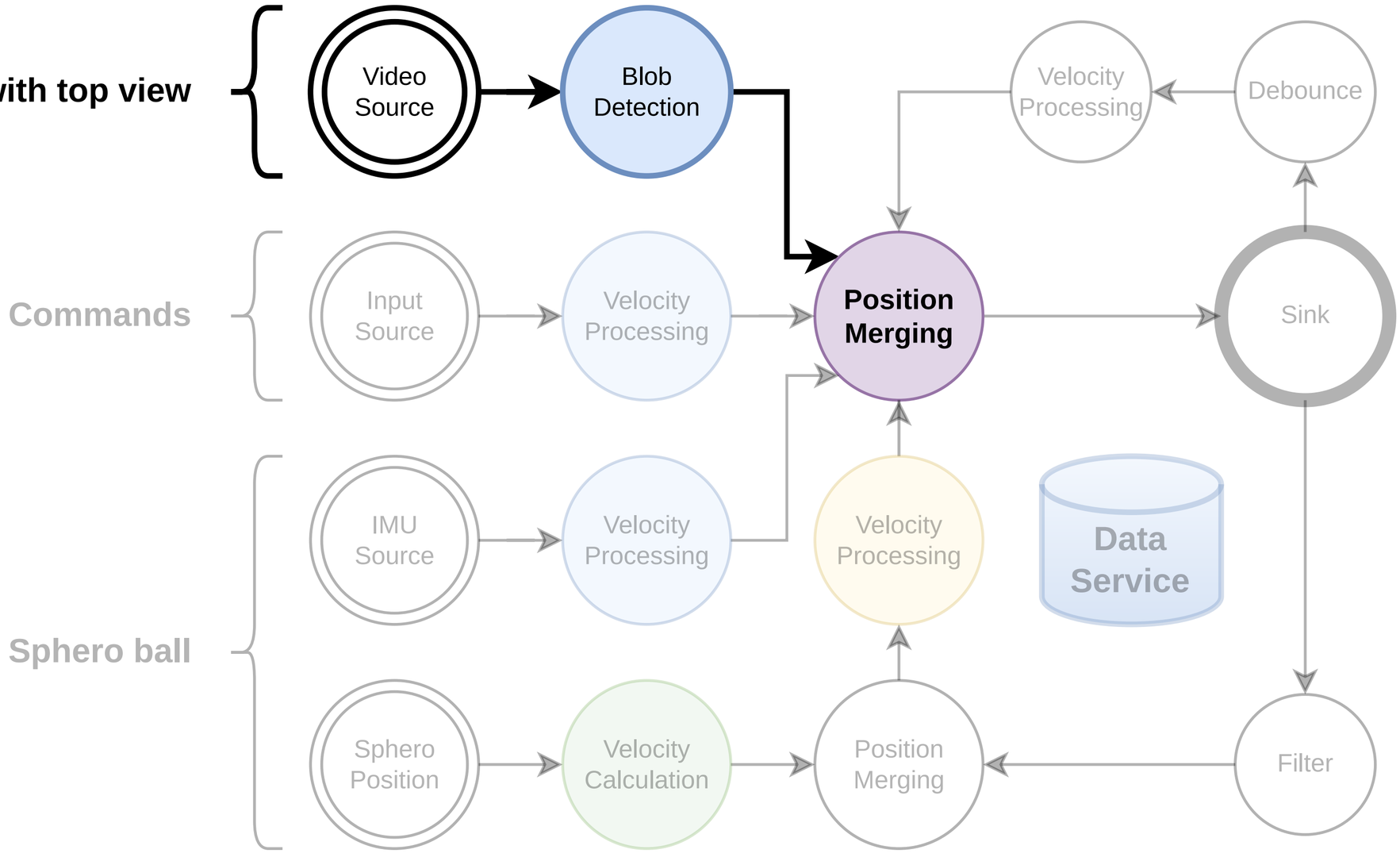
Example ...

OpenHPS



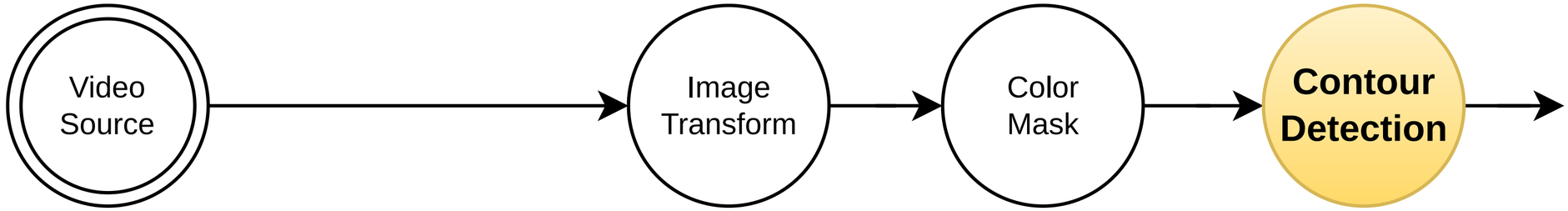
Example ...

OpenHPS

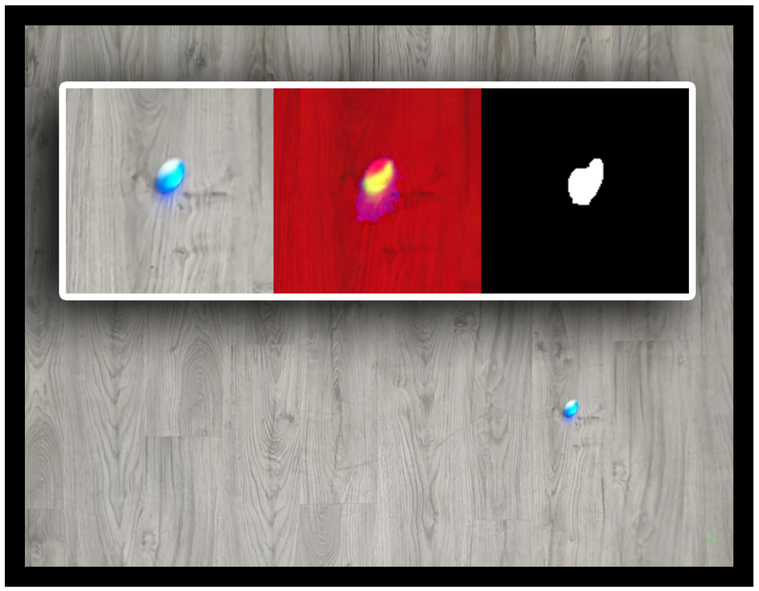


Example ...

OpenHPS



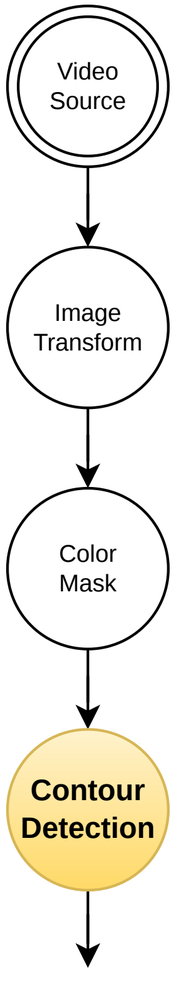
Original



Transformed & Mask

Example ...

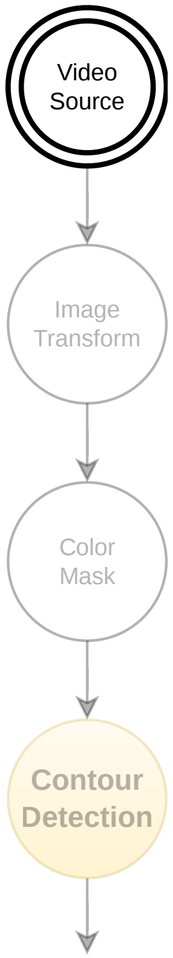
OpenHPS




```
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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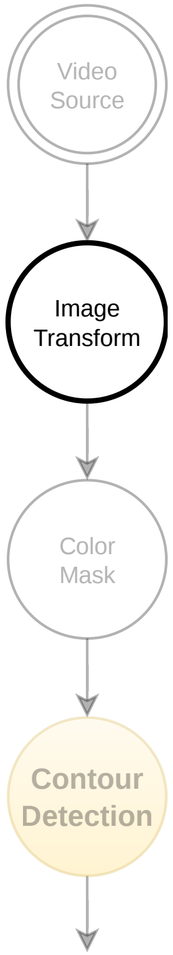
GraphBuilder.create()
  .from(new VideoSource({
      autoPlay: true,
      fps: 30,
      throttleRead: true,
      source: new CameraObject("sphero_video")
  }).load("/dev/video2"))
  .via(new ImageTransformNode({
      src: [
          new OpenCV.Point2(307, 120),
          new OpenCV.Point2(1473, 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




```
GraphBuilder.create()
  .from(new VideoSource({
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      fps: 30,
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  }).load("/dev/video2"))
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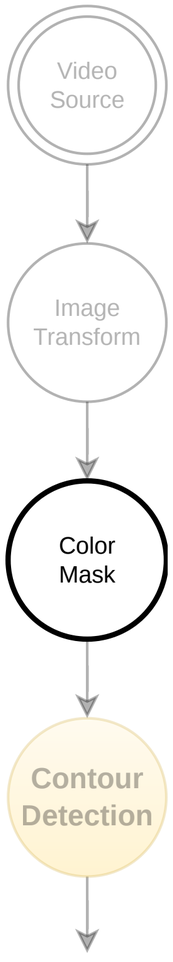
Example ...

OpenHPS

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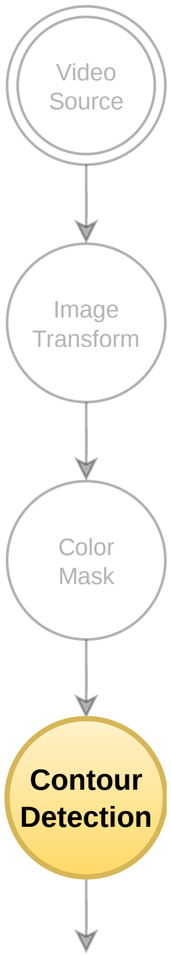
Example ...

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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class ContourDetectionNode extends ProcessingNode<VideoFrame> {
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OpenCV: Contour Detection

OpenHPS

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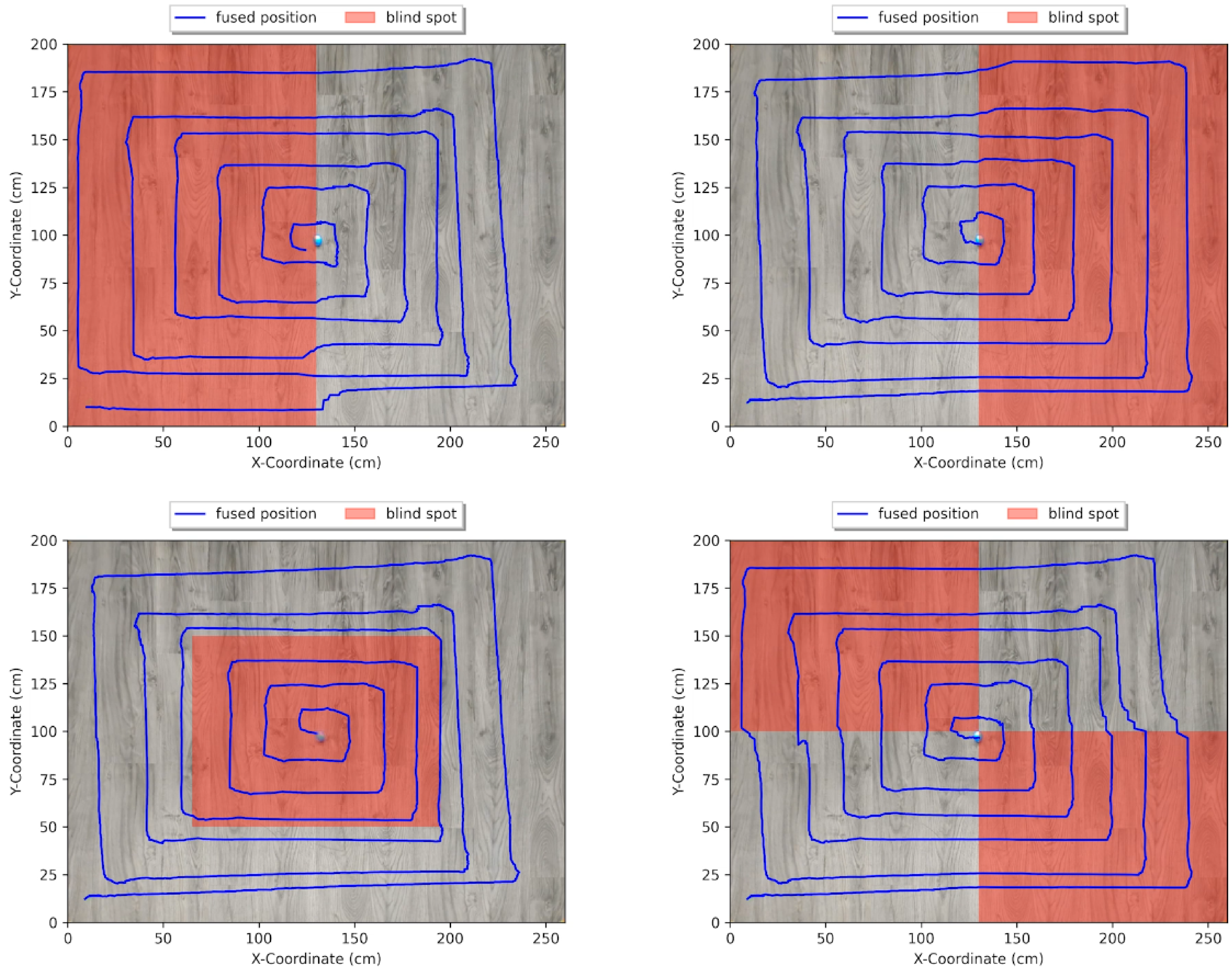
                const m = contours[0].moments();
                const center = new OpenCV.Vec2(m.m10 / m.m00, m.m01 / m.m00);
                // Use the center as the 2D pixel position
                const position = new Absolute2DPosition(center.x, center.y);
                position.unit = LengthUnit.CENTIMETER; // Convert later
                position.accuracy = Math.sqrt(contours[0].area);
                frame.addObject(new DataObject("ball").setPosition(position));
            }
            resolve(frame);
        });
    }
}
```

OpenHPS


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

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

Maxim Van de Wynckel
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