The Journal of Open Source Software

# OpenHPS: A Modular Framework to Facilitate the Development of FAIR Positioning Systems

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**DOI:** 10.xxxxxx/draft

**Software**

- Review
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**Editor:** Open Journals

**Reviewers:**

- @openjournals

**Submitted:** 01 January 1970
**Published:** unpublished





## Abstract

Positioning systems determine the location of people and objects using various technologies and algorithms. While GPS dominates outdoor positioning, indoor and smaller-scale systems often require alternative technologies for improved latency, accuracy, or efficiency. These systems are often developed as single-use prototypes with no standard data format, hindering reusability and expansion. OpenHPS addresses these challenges by providing a modular, graph-based framework for creating versatile positioning systems on multiple platforms. It supports a wide range of algorithms and enables extensibility through custom nodes for sensor fusion and algorithm integration.

## Keywords

Hybrid positioning systems, interoperable positioning systems, indoor positioning, stream processing, linked data, RDF

# Statement of Need

Existing positioning systems or frameworks (Georgiou et al., 2015; Pustka et al., 2011; Scholl, 2020) often focus on specific use cases, platforms, or a set of algorithms. While this facilitates the deployment of a system, it limits the flexibility to design or reuse custom algorithms and systems. In systems developed for academic purposes (García et al., 2015), proprietary systems are often difficult to replicate, extend, or deploy in a production-ready environment due to the use of software such as MatLab. Furthermore, the data produced by such systems is often unstandardised. OpenHPS was created to address these issues by providing a modular framework that allows developers and researchers to create positioning systems for a wide range of use cases. The framework and data created with our framework is designed to be interoperable, allowing developers to share their algorithms and data with others. Using additional modules that add support for Solid (Van de Wynckel & Signer, 2022a) and DHTs, we have enabled the development of findable, accessible, interoperable and reusable (FAIR) positioning systems.

## Framework Overview

`OpenHPS` is an open-source hybrid positioning system framework written in TypeScript. It runs on the server (Node.js), in the browser, or within hybrid mobile applications. The general design of a positioning system created using OpenHPS consists of a graph with a set of nodes that process data. Background services can be added to the graph to persist data or to communicate with other systems. Our decision to use TypeScript compared to using a low-level language was based on the goal of achieving cross-platform reusability.

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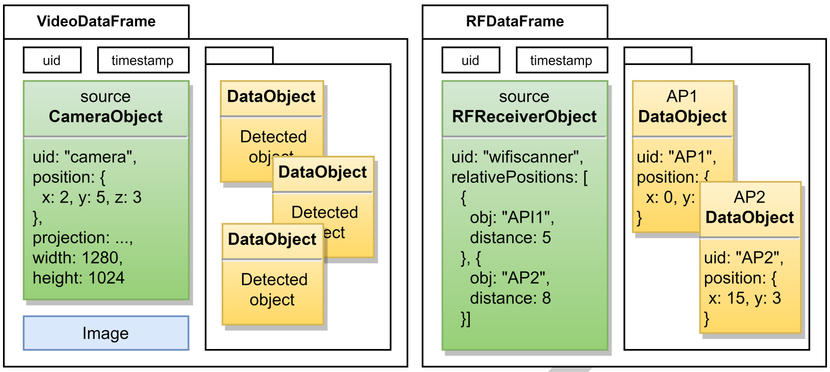


**Figure 1:** `DataFrames` and `DataObjects`

All concepts, ranging from positions to sensor values, can be expressed in various ways with varying units, enabling OpenHPS to support both small-scale use cases such as tracking a pen on a paper to larger use cases such as tracking airplanes across the globe. Our framework uses stream-based processing of `DataFrames` which contain all time-sensitive information. These frames contain one or more `DataObjects` as illustrated in Figure 1, which indicate the spatial objects relevant for the information within the data frame. This enables the tracking of multiple actors, unlike frameworks such as ROS (Quigley et al., 2009).

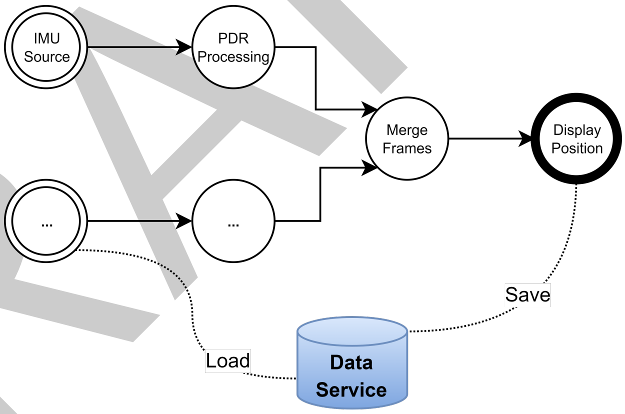


**Figure 2:** OpenHPS graph of a positioning system

Any data pushed through the graph can be serialised to JSON or RDF data using the POSO ontology (Van de Wynckel & Signer, 2022b), enabling interoperability between systems. Each node in the graph represents a step in the processing of data frames from source to sink as shown in Figure 2. A `SourceNode` generates information, a `ProcessingNode` processes information and a `SinkNode` consumes information.

OpenHPS is modular by design, mainly due to the ability to extend data frames and objects. These extensions allow for different data objects, including different sensors like cameras, IMU sensors or spatial landmarks such as Bluetooth beacons. Each node in a graph can be extended as well, allowing the creation of custom algorithms that can be added or removed from a positioning system. Researchers can focus on the prototyping of new algorithms without having to worry about the integration of these algorithms into a larger system.

## Interoperability

Our framework is designed to offer FAIR positioning systems, leveraging its open architecture and the data it produces. Modules such as `@openhps/rdf` and `@openhps/solid`, we have enabled developers to serialise their data to RDF and store it in Solid Pods. This facilitates the creation of positioning systems that are transparent and privacy-preserving, while also ensuring that other positioning systems or consumer applications can access the data, regardless of whether they were created with OpenHPS. With various extensions such as semantic beacons (Van de Wynckel & Signer, 2023), we enable the discovery of these systems and the data they produce.

### Performance

OpenHPS uses JavaScript at runtime. To overcome the challenges associated with creating real-time dataflows, our graph can be executed using Web Workers (Van de Wynckel & Signer, 2020). All data transmitted through our graph is serialisable, eliminating the need for developers to handle this serialisation or communication between workers. In addition to the ability to run graphs on multiple workers, communication nodes, such as MQTT, enable developers to offload the processing of complex tasks to other servers or dedicated processors. For more high-demanding algorithms, modules like `@openhps/opencv` and `@openhps/openvslam` provide C++ bindings to low-level libraries. While these bindings may not achieve the same performance, the ability to reuse other libraries is part of the main requirements.

# Examples of Research Work

OpenHPS has been a building block for various research that has been used in indoor positioning systems (Van de Wynckel & Signer, 2021a), and its ability to serialise location data to RDF has been demonstrated in an application that aims to preserve privacy and transparency using Solid Pods (Van de Wynckel & Signer, 2022a). Further, OpenHPS was used in the SemBeacon demonstrator application (Van de Wynckel & Signer, 2023) that is written in CapacitorJS and uses the framework to deserialise positioning data and positioning systems. Modules have been created for other academic projects, such as the FidMark ontology (Van de Wynckel et al., 2024), which provides fiducial marker classification within the framework. OpenHPS's modular node design and domain focus facilitate the sharing of algorithms and findings, as well as the rapid creation of prototypes and demonstrators that make use of location data. Finally, OpenHPS and the related modules have been used to collect several datasets that can be used by researchers to evaluate their algorithms (Van de Wynckel & Signer, 2021b), (Van de Wynckel, 2025), (Van de Wynckel & Signer, 2025).



# References

García, E., Poudereux, P., Hernández, Á., Ureña, J., & Gualda, D. (2015). A Robust UWB Indoor Positioning System for Highly Complex Environments. *2015 IEEE International Conference on Industrial Technology (ICIT)*, 3386–3391. https://doi.org/10.1109/ICIT.2015.7125601

Georgiou, K., Constambeys, T., Laoudias, C., Petrou, L., Chatzimilioudis, G., & Zeinalipour-Yazti, D. (2015). Anyplace: A Crowdsourced Indoor Information Service. *Proceedings of the International Conference on Mobile Data Management: Systems, Services and Middleware (MDM 2015)*, 291–294. https://doi.org/10.1109/MDM.2015.80

Pustka, D., Huber, M., Waechter, C., Echtler, F., Keitler, P., Newman, J., Schmalstieg, D., & Klinker, G. (2011). Automatic Configuration of Pervasive Sensor Networks for Augmented Reality. *IEEE Pervasive Computing*, *10*(3), 68–79. https://doi.org/10.1109/MPRV.2010.50

Quigley, M., Conley, K., Gerkey, B., Faust, J., Foote, T., Leibs, J., Wheeler, R., & Ng, A. Y. (2009, May). ROS: An Open-Source Robot Operating System. *Proceedings of the International Workshop on Open Source Software*. https://api.semanticscholar.org/CorpusID:6324125

Scholl, Z. (2020). *The Framework for Internal Navigation and Discovery (FIND)*. https://github.com/schollz/find3

Van de Wynckel, M. (2025). *Garage Positioning Dataset*. Kaggle. https://doi.org/10.34740/KAGGLE/DS/6654647

Van de Wynckel, M., & Signer, B. (2022a). A Solid-based Architecture for Decentralised Interoperable Location Data. *Proceedings of the 12th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2022), CEUR Workshop Proceedings*, *3248*. https://ceur-ws.org/Vol-3248/paper11.pdf

Van de Wynckel, M., & Signer, B. (2021a). Indoor Positioning Using the OpenHPS Framework. *Proceedings of the 11th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2021)*, 1–8. https://doi.org/10.1109/IPIN51156.2021.9662569

Van de Wynckel, M., & Signer, B. (2020). *OpenHPS: An Open Source Hybrid Positioning System*. Vrije Universiteit Brussel. https://doi.org/10.48550/ARXIV.2101.05198

Van de Wynckel, M., & Signer, B. (2021b). *OpenHPS: Single Floor Fingerprinting and Trajectory Dataset*. https://doi.org/10.5281/zenodo.4744380

Van de Wynckel, M., & Signer, B. (2022b). POSO: A Generic Positioning System Ontology. *Proceedings of the 21st International Semantic Web Conference (ISWC 2022)*. https://doi.org/10.1007/978-3-031-19433-7_14

Van de Wynckel, M., & Signer, B. (2023). SemBeacon: A Semantic Proximity Beacon Solution for Discovering and Detecting the Position of Physical Things. *Proceedings of the 13th International Conference on the Internet of Things (IoT 2023)*. https://doi.org/10.1145/3627050.3627060

Van de Wynckel, M., & Signer, B. (2025). *Sphero Dead Reckoning and CV Tracking Dataset*. Kaggle. https://doi.org/10.34740/KAGGLE/DS/6760212

Van de Wynckel, M., Valadez, I., & Signer, B. (2024). FidMark: A Fiducial Marker Ontology for Semantically Describing Visual Markers. *Proceedings of the Semantic Web (ESWC 2024)*, 235–250. https://doi.org/10.1007/978-3-031-60635-9_14