

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

Maxim Van de Wynckel¹ and Beat Signer¹

¹ Vrije Universiteit Brussel, Belgium

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Abstract

Positioning systems are a collection of technologies and algorithms that can help to determine the location of people and objects. While outdoor positioning systems primarily use satellites such as GPS to perform the tracking, many different technologies exist that can offer better latency, accuracy or battery efficiency depending on the use case. These use cases can range from indoor positioning systems where there is no standardised technology to smaller scale positioning systems such as tracking the location of a pen on a piece of paper. In the research domain of positioning and tracking, these novel types of systems are often implemented as single-use prototypes with no common data format, making it difficult to replicate or expand. OpenHPS was created as a framework to enable the creation of positioning systems for a wide range of use cases and offers a wide range of commonly used algorithms that can be extended when needed. The creation of a positioning system using our framework is graph based, allowing developers to share individual custom *nodes* that implement new algorithms or fuse sensor data from a variety of technologies.

Keywords

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

Statement of Need

Existing positioning systems or frameworks such as AnyPlace ([Georgiou et al., 2015](#)) focus on a specific use case, platform or set of algorithms. While this facilitates the development of a positioning system, it also limits the freedom to design custom algorithms or positioning systems. In systems developed for academic purposes, proprietary systems are created that are difficult to replicate, expand or implement in a production-ready environment due to the use of software such as MatLab. 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 positioning systems created with our framework are designed to be interoperable, allowing developers to share their algorithms and positioning systems with others. Using additional modules that add support for Solid ([Van de Wynckel & Signer, 2022](#)) and DHT, 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 can be run on the server using NodeJS, the browser or even hybrid mobile applications such as NativeScript, React-Native and CapacitorJS. The general design of a positioning system created

using our framework 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.

All concepts, ranging from positions to sensor values can be expressed in various ways with varying units, allowing OpenHPS to be used for 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. Inside these frames can be one or more DataObjects which indicate the spatial objects that are relevant for the information within the data frame.

Both this information can be serialised to JSON or RDF data using the POSO ontology (?), enabling the interoperability between systems. Each node in the graph represent a step in the processing of data frames from source to sink. 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 such as different sensors such as 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 with ease. 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, both using the open approach of the framework as well as the data these systems produce. With our 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 allows for 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 if they are created using OpenHPS. Extensions such as @sembeacon/openhps provide support for semantic beacons (Van de Wynckel & Signer, 2023) that can enable the discovery (i.e., findability) of these systems and the data they produce.

Performance

Since our framework uses TypeScript, it uses JavaScript at runtime, which is single-threaded by default. To overcome the challenges associated with this when creating real-time stream processing systems, our graphs or portions of the graph can be executed with the help of web workers. All data transmitted through our graph is serialisable, which prevents the need for developers to handle this serialisation or the communication between web workers themselves.

In addition to the ability to run graphs on multiple workers, our communication nodes such as MQTT, combined with the serialisability of data, allows developers to offload the processing of complicated tasks to other servers or dedicated processors. For more high-demanding algorithms such as computer vision and visual SLAM, modules such as @openhps/opencv and @openhps/openslam create C++ bindings in NodeJS.

Examples of Research Work

OpenHPS has been a building block for various research such as its use within indoor positioning systems (Van de Wynckel & Signer, 2021), its ability to serialise location data to RDF in a demonstrator application that aims to preserve privacy and transparency using Solid-pods (Van de Wynckel & Signer, 2022) and its use within the SemBeacon demonstrator application (Van de Wynckel & Signer, 2023) that is written in CapacitorJS and uses OpenHPS to deserialise positioning data and positioning systems. Modules have been created for other academic projects such as the FidMark (Van de Wynckel et al., 2024) ontology that provides fiducial

86 marker classification within the framework. The ability for OpenHPS to contain modular nodes
87 and its use within the domain of positioning systems can allow for easier sharing of algorithms
88 and findings, as well as the rapid creation of prototypes and demonstrators that make use of
89 location data. Finally, OpenHPS and the related modules have been used to collect several
90 datasets that can be used by researchers to evaluate their algorithms (?).

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