H2020 – FOF – 09 – 2015

Innovation Action

HORSE

Smart integrated immersive and symbiotic human-robot collaboration system controlled by Internet of Things based dynamic manufacturing processes with emphasis on worker safety

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680734

D4.5 User Handbook

Report Identifier:	D4.5		
Work-package, Task:	WP4, Task 4.2	**Status – Version:**	1.0
Distribution Security:	PU	**Deliverable Type:**	R
Editor:	Venelin Arnaudov (PROS)		
Contributors:	Tuncher Shefkaev (PROS)		
Reviewers:	TUM, ED		
Quality Reviewer:	ED		

Keywords:	
Project website: www.horse-project.eu	

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Abbreviations

API	Application Programming Interface
BPMN	Business Process Management Notation
BPMS	Business Process Management Systems
BSD	Berkeley Software Distribution (Unix distribution)
CEA	Commissariat à l'Énergie atomique et aux Énergies alternatives (French Alternative Energies and Atomic Energy Commission)
CMMN	Case Management Model and Notation
D2.2	HORSE Deliverable D2.2 - Complete System Design
D3.6	HORSE Deliverable D3.6 - Early version of situation awareness software for human and non-human agents in a manufacturing work cell(*)
D3.11	HORSE Deliverable D3.11 - Final Version of HORSE Cross-Domain Messaging(*)
D3.13	HORSE Deliverable D3.13 - Final Version of the Middleware for HORSE Execution Domains(*)
DB	Database
DDL	Device Definition Language
DMN	Decision Model and Notation
ED	European Dynamics
FZI	Forschungszentrum Informatik
HEG	HORSE Exec Global (design component)
HEL	HORSE Exec Local (design component)
HM	HORSE Messaging
HMI	Human Machine Interface
JDBC	Java Database Connectivity

JSON	JavaScript Object Notation
MPMS	Manufacturing Process Management System
OPC-UA	OPC Unified Architecture
PLC	Programmable logic controller
POJO	Plain Old Java Object
PROS	ProSyst Software GmbH (since 2016, acquired by Bosch Software Innovations GmbH)
REST	Representational State Transfer
ROS	Robot Operating System
SME	Small and medium-sized enterprises
SOAP	Simple Object Access Protocol
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
TUE	Technical University of Eindhoven
TUM	Technical University of Munich
URDF	Unified Robot Description Format

(*) This HORSE deliverable is not public. A copy could be granted upon the discretion of the project's Coordination Board.

Executive Summary

This deliverable provides a guideline for installation of the HORSE components and supporting infrastructure. The most of these components are developed as extensions or on top of existing products and implement state of the art technologies. The contact data of the component developers or product support is provided as a reference for further information and assistance.

1 Introduction

1.1 Objectives

The key objective of the HORSE project is to inform and enable SMEs to adopt robotic technologies and collaborative solutions. For this purpose, the HORSE consortium designed and implemented a flexible framework (a collection of components) that can be easily tailored to the needs of the entrepreneurs.

The resulted distributed solution is based on the state of the art technologies and products in the domain of Industry 4.0, Internet of Things robotics and business processes. This document should help the prospective users to evaluate the cost of procuring of equipment and estimation of the efforts for setup and maintenance of the desired constellation of HORSE components.

1.2 Structure

The key part of the document is the section containing description of the installation specifics for each component and the requirements towards the IT infrastructure and equipment (machines, sensors. Some more detailed setup and operation instructions have been provided as appendices.

2 HORSE Components

2.1 Overview

This chapter provides a short introduction of the modules implementing the building blocks identified in the HORSE system design (HORSE Deliverable 2.2[1]). The presented modules should be configured and customised in order to be able to realise the specific scenarios of the end users.

Figure 1 the two major types of functional domains of grouping the HORSE modules.

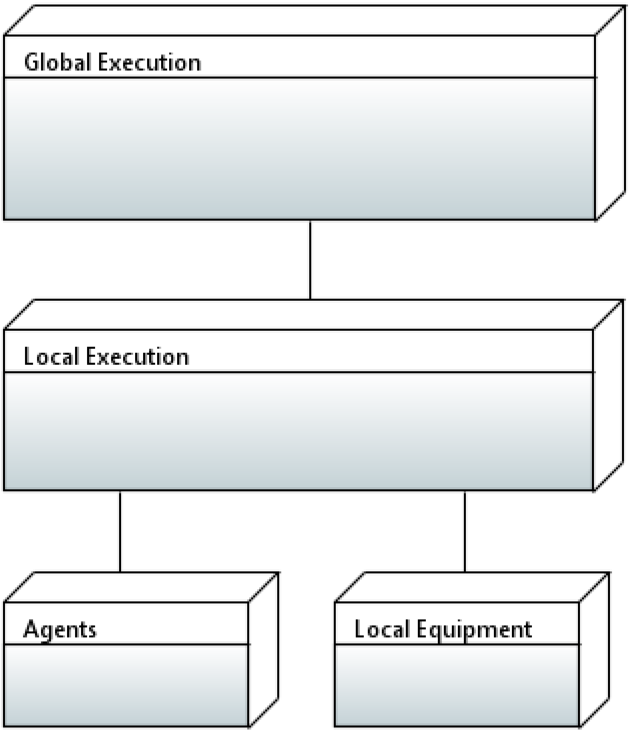


Figure 1: Deployment Example

Each deployment of the HORSE framework should feature one Global Execution domain, comprising of the components responsible for the global process management and global situation awareness. The detailed view of the modules in this group is given in Figure 2.

[1] A public version of the deliverable is available at http://www.horse-project.eu/Publications

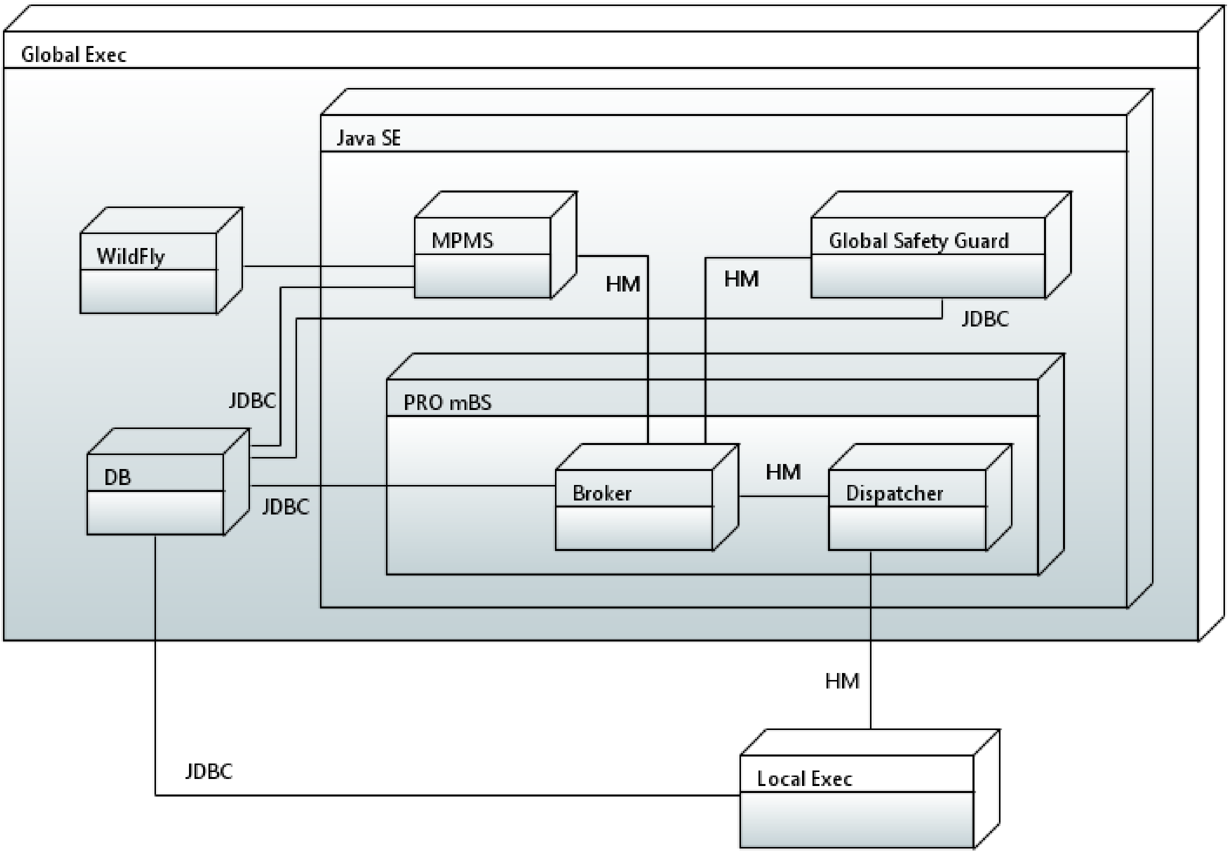


Figure 2: HORSE Exec Global Deployment

The components interacting with the agents (human and automated), local equipment and sensors could be deployed in one or more groups in the relevant work cells. Figure 3 gives a more detailed view of a typical deployment of the Local Execution functional domain.

The main interface for communication between the components is the exchange of messages over the HORSE Messaging Middleware. These connections are marked with “HM”.

The HORSE Broker (one for each functional domain) is responsible for forwarding the messages to the designated recipients. The communication between the domains is realised through the HORSE Dispatcher (one for the entire system) who is mediating between the brokers.

Another protocol used for communication between the components dealing with robots and other time sensitive equipment is ROS. The conversion of the messages exchanged over the HORSE Messaging Middleware and the ROS messages is done by the HORSE-ROS Bridge.

The connection to the local DB server (usually residing in Global Execution domain) is done over JDBC protocol. For a better readability of Figure 3, the JDBC connections of the single components are not displayed. Instead, there is one collective connection between the Local Execution domain and the DB server.

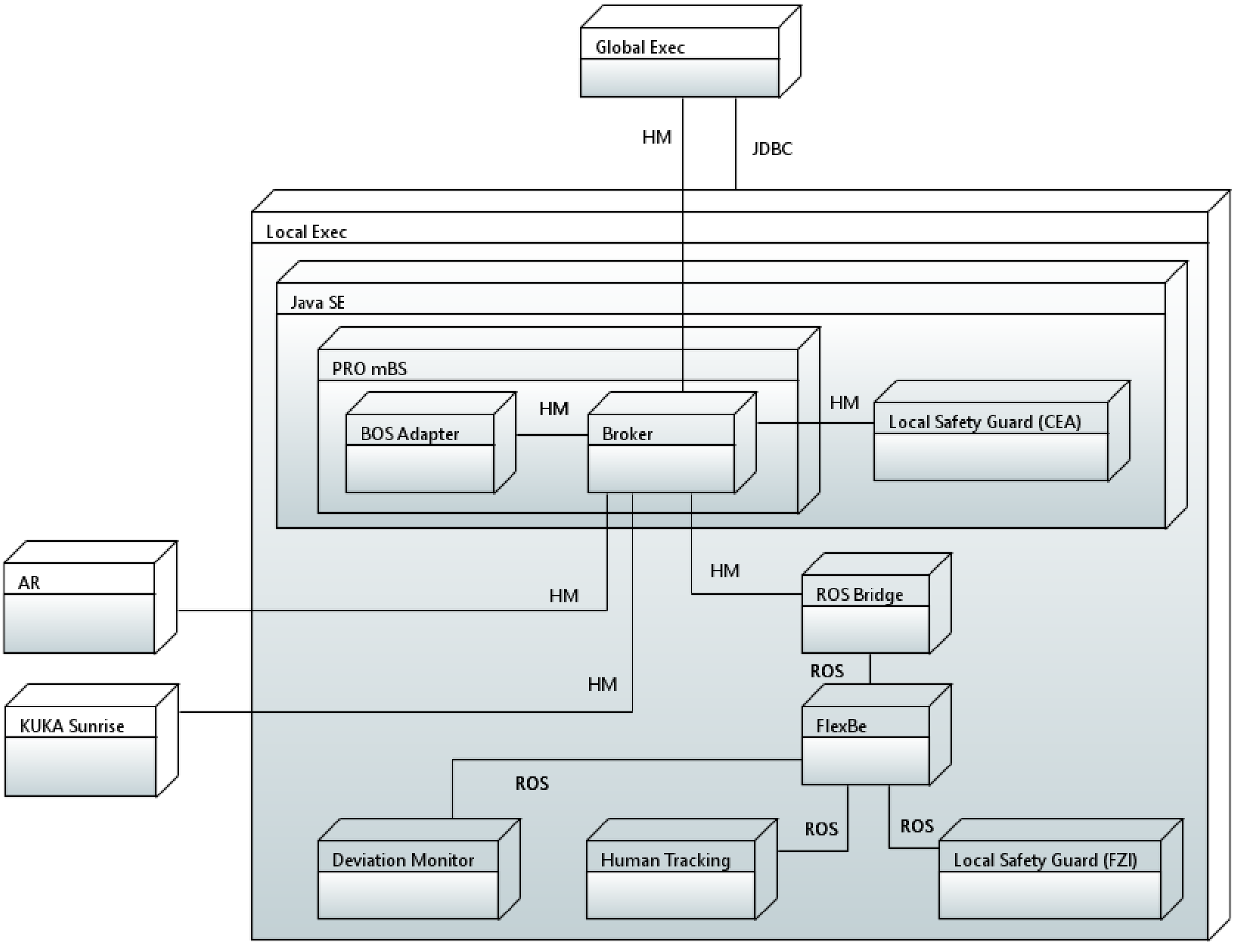


Figure 3: HORSE Exec Local Deployment

The next sections provide more details on the installation and configuration specifics of each HORSE module.

2.2 *Messaging Middleware*

2.2.1 Short Description

The HORSE Messaging Middleware is responsible for communication between the HORSE components. It consists of:

- Broker, deployed in each functional domain and enabling the com
- Dispatcher, one instance, mediating between the brokers
- Client specification and a reference implementation
- Agent Manager, providing information about the connection status of the messaging clients
- Lifecycle management of the connections to the agents
- Format of the JSON based message

Each HORSE component willing to communicate over the HORSE Messaging Middleware should implement a WebSockets Client and register it to the local Broker (implementing WebSockets Server).

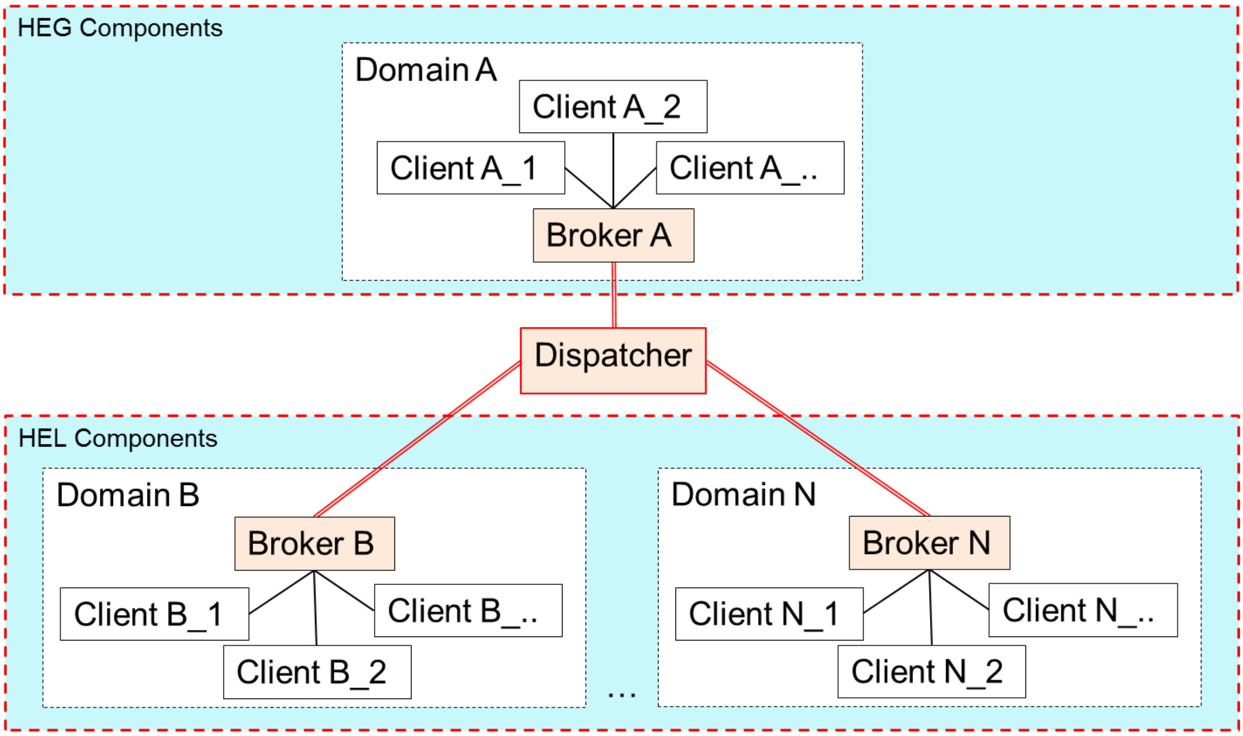


Figure 4: HORSE Messaging Topology

Figure 4 shows the topology of the HORSE Messaging components. It is well seen that the same approach is applied to all functional domains and the titles HEG (HORSE Exec Global) and HEL (HORSE Exec Local) are serving organisational purposes.

The key components of the HORSE Messaging Middleware (Broker, Dispatcher and Agent Manager) are implemented as OSGi bundles operating in the Bosch IoT Gateway Software (former ProSyst mBS). The same approach is applied for the BOS Adapter (the interface to the industrial equipment at Bosch Pilot Test site).

Figure 5 presents the components of the HORSE Messaging Middleware in their execution environment.

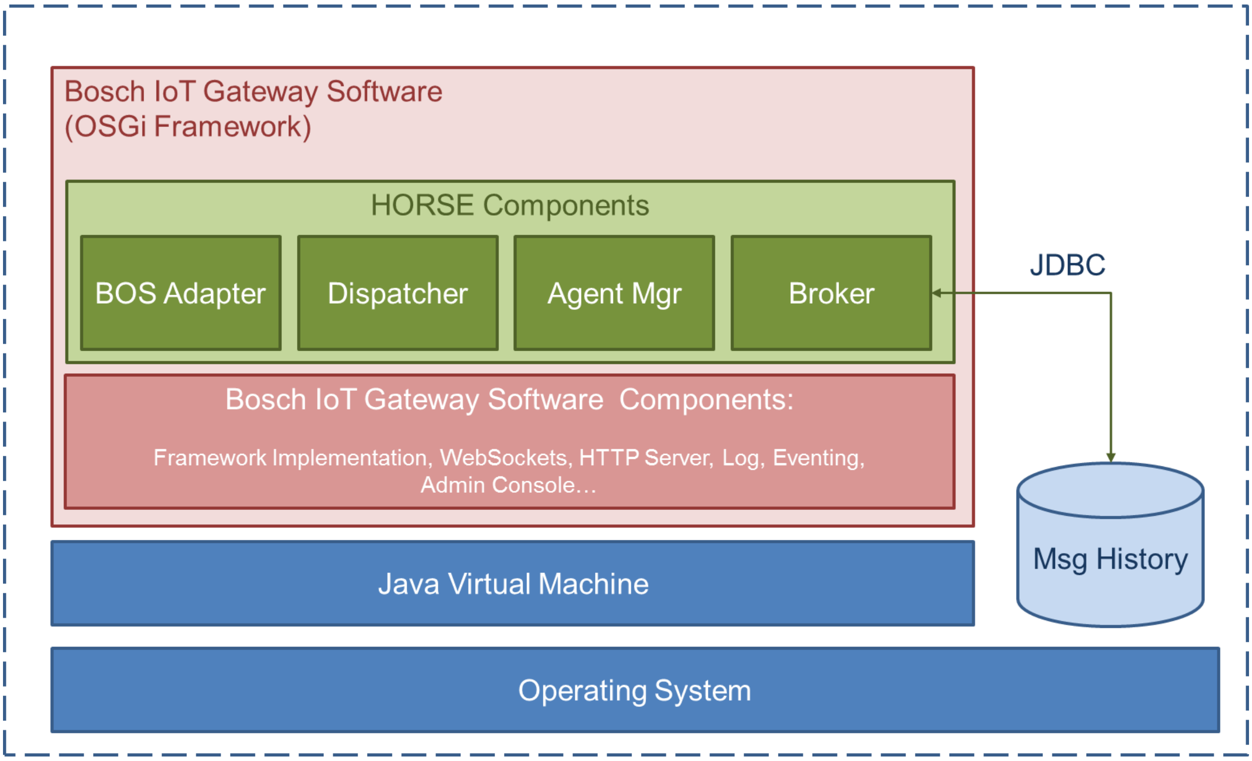

Bosch IoT Gateway Software
(OSGi Framework)
HORSE Components
BOS Adapter
Dispatcher
Agent Mgr
Broker
JDBC
Bosch IoT Gateway Software Components:
Framework Implementation, WebSockets, HTTP Server, Log, Eventing, Admin Console…
Msg History
Java Virtual Machine
Operating System

Figure 5: Execution Environment for PRO modules

The HORSE Messaging Middleware has been described in HORSE deliverables D3.11 Final Version of HORSE Cross-Domain Messaging and D3.13 Final Version of the Middleware for HORSE Execution Domains.

2.2.2 System Requirements

CPU: x86, ARM

OS: Windows, Linux, MacOS

RAM: at least 4 GB

Disk Space: at least 2 GB for storing the log files

Java VM: Oracle 1.8, Open JDK 1.8

DB: postgreSQL (local or remote)

OSGi implementation: Bosch IoT Gateway Software (former ProSyst mBS), version 8.1.4 or higher

2.2.3 Legal Status

The HORSE Messaging Middleware components and the underlying Bosch IoT Gateway Software are provided free of charge to the consortium members and Open Calls partners for the duration of the project. For a further use, please contact the vendor Bosch Software Innovations GmbH.

2.2.4 Installation Guide

- *See Appendix A.*

2.2.5 Administration and support

- See the usage guide in Appendix A
- For further assistance contact:
  Bosch Software Innovations GmbH,
  Venelin Arnaudov (Venelin.Arnaudov@bosch-si.com)

2.3 HORSE-ROS Bridge

2.3.1 Short Description

The HORSE-ROS Bridge is a component that allows the communication between native ROS nodes (the Open-Source framework "Robot Operating System") and nodes using the HORSE middleware. It enables the middleware clients to use the full ROS functionalities available to native ROS nodes. In order to allow the forwarding of HORSE events originating at native ROS nodes to middleware nodes, it offers a ROS service interface to forward arbitrarily complex messages.

2.3.2 System Requirements

The HORSE-ROS Bridge requires Ubuntu Linux 16.04 with the ROS Kinetic framework.

2.3.3 Legal Status

The HORSE-ROS Bridge is distributed under the BSD license.

2.3.4 Installation Guide

The software and the installation guidelines are available at the HORSE website, under the menu “About HORSE -> Publications”.

2.3.5 Administration and support

For help and support contact FZI:

- Gabriele Bolano, bolano@fzi.de
- Christian Jülg, juelg@fzi.de

2.4 MPMS

2.4.1 Short Description

The HORSE Design Global and the Global Execution modules of HORSE Exec Global of HORSE Software Architecture are the so called “Manufacturing Process Management System” (MPMS), the information system components which enable the design and execution of a manufacturing process which contains two or more tasks. In this Chapter we describe the technical details of MPMS.

The MPMS is the collection of subsystems responsible to orchestrate the tasks of agents in the manufacturing processes. Orchestration is dependent on the design of the processes and agents. The

MPMS includes the functionality to design processes and describe agents, and execute the processes by assigning activities to agents. It is built on traditional Business Process Management Systems (BPMS), with adaptations to fit the manufacturing domain. A Process Modeller is available for designing processes and a Process Engine undertakes the enactment of those.

MPMS communicates, through the Middleware, with the Local modules which eventually trigger the agents.

The management of the high level tasks is handled by the MPMS. Its user interface is executed by a web server like WildFly or Apache.

2.4.2 System Requirements

MPMS is built on an open-source BPMS called Camunda BPM, which we have adapted and extended to the HORSE needs. Camunda is a Java-based framework natively supporting BPMN for workflow and process automation, DMN for Business Decision Management and CMMN for Case Management. It has both modelling tools and execution environment as a complete platform. In Figure 6 we present its main software components and the overall architecture.

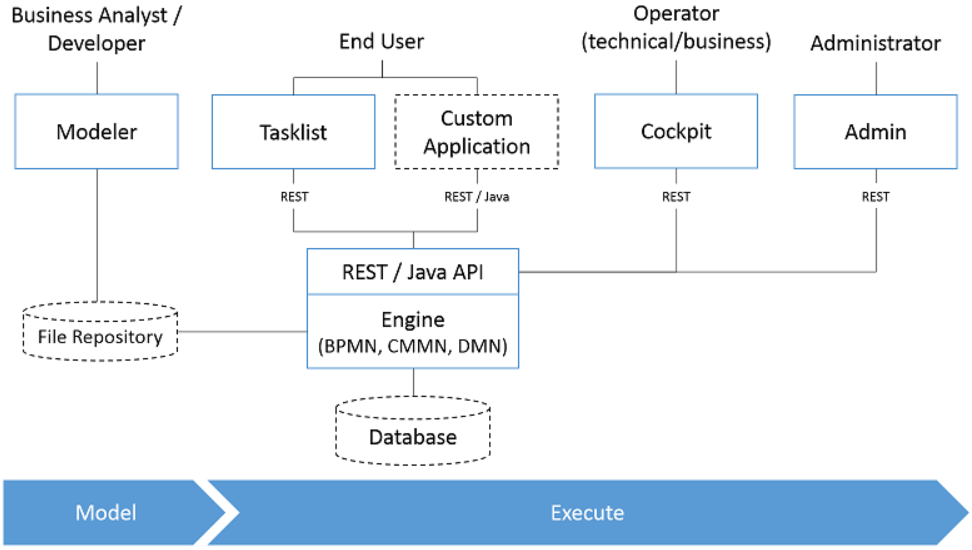


Figure 6: Camunda BPM overview

<u>Modeller</u>

The standalone application for modelling processes is available on [Camunda Modeler - https://camunda.org/download/modeler/](https://camunda.org/download/modeler/).

<u>Engine</u>

Camunda BPM platform is a flexible framework which can be deployed in different scenarios:

- Embedded Process Engine
- Shared, Container-Managed Process Engine

- Standalone (Remote) Process Engine Server

In HORSE framework, we use the Shared, Container-Managed Engine (Figure 7):

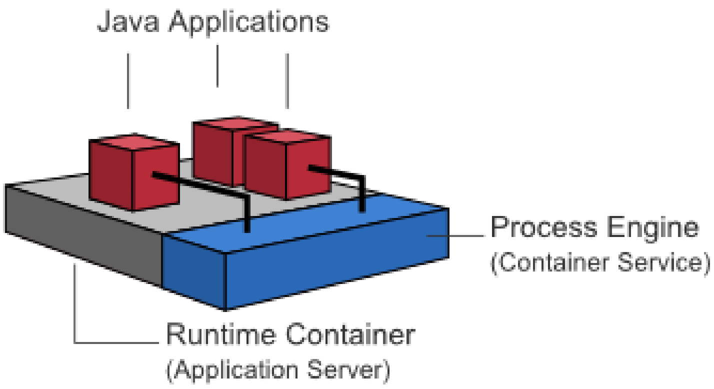


Figure 7: Shared, Container-Managed Process Engine

<u>Web applications (Tasklist, Cockpit, Admin)</u>

The Camunda BPM web applications are based on a RESTful architecture.

Frameworks used:

- JAX-RS based Rest API
- AngularJS
- RequireJS
- jQuery
- Twitter Bootstrap

<u>Supported Environments</u>

Camunda BPM platform runs in every Java-runnable environment. Depending on the version of Camunda BPM, the following environments can be supported:

<u>Container/Application Server for Runtime Components</u>

- Apache Tomcat 6.0 / 7.0 / 8.0
- JBoss Application Server 7.2 and JBoss EAP 6.1 / 6.2 / 6.3 / 6.4 / 7.0
- Wildfly Application Server 8.2 / 10.1

<u>Databases</u>

- MySQL 5.6 / 5.7
- MariaDB 10.0
- Oracle 10g / 11g / 12c
- IBM DB2 9.7 / 10.1 / 10.5 / 11.1 (excluding IBM z/OS for all versions)
- PostgreSQL 9.1 / 9.3 / 9.4 / 9.6

- Microsoft SQL Server 2008 R2 / 2012 / 2014
- H2 1.4

Web Browser

- Google Chrome latest
- Mozilla Firefox latest
- Internet Explorer 9 / 10 / 11

Java

- Java 6 / 7
- Java 8 (if supported by your application server/container)

Java Runtime

- Sun/Oracle Hot Spot 6 / 7 / 8
- IBM® J9 virtual machine (JVM) 6 / 7 / 8
- OpenJDK 7 / 8
- Oracle JRockit 6 - R28.2.7

Camunda Modeler

- Windows 7 / 10
- Mac OS X 10.11
- Linux

Camunda BPM is available as a full distribution, available on Camunda Download - https://camunda.org/download/.

It bundles:

- Process Engine configured as shared process engine
- Runtime Web Applications (Tasklist, Cockpit, Admin)
- Rest API
- Container / Application Server itself

For HORSE we use Camunda BPM 7.7.0 – WildFly 10 Distribution, using all above components.

TUE implemented the application processes that interact with the engine.

For registering the MPMS as a Websocket Agent in the Message Bus, we use Java API for WebSocket JSR 356, which defines a standard API for creating websocket applications. We implement a @ClientEndpoint POJO, which is responsible to open/close a websocket connection (we only need the IP address and the port number of the Message Bus server to register MPMS as a client node) and send/receive messages.

For DB integration, in the default configuration of the Camunda BPM distribution, the database schema and all required tables are automatically created in an H2 database when the engine starts up for the first time. These are internal engine data.

For "business/application" data, like for example the Product DB or Agent Def. DB., we use a PostgreSQL JDBC driver to connect to the PostgreSQL DB Server. We implement a "horse" DB, with all the right datatables.

PC Requirements

For deploying MPMS in a local desktop PC, not any special requirements are needed. A powerful processor, a lot of RAM memory and a decent graphics card is sufficient. The following specs are recommended:

- Processor: Intel Core i7-7700 @ 3.60GHz / Intel Core i7-6700K @ 4.00GHz / Intel Core i7-7700K @ 4.20GHz / Intel Core i7-8700K @ 3.70GHz
- Storage: SATA 2.5 SSD (e.g. 256 GB)
- RAM: 32GB DDR4-2133 DIMM (2x16GB)
- Graphics Card: Any standard modern graphics card

Monitor, keyboard and mouse are essential.

A laptop could also work:

Processor: Intel Core i7-7700HQ @ 2.80GHz / Intel Core i7-6770HQ @ 2.60GHz.

2.4.3 Legal Status

The Camunda Community Platform is licensed under the Apache License 2.0 - http://www.apache.org/licenses/LICENSE-2.0.html. Third-party libraries or application servers included are distributed under their respective licenses. We present below a list of the required dependencies we use in MPMS (to provide core functionality). Full list including optional dependencies can be found on Camunda - Third party libraries - https://docs.camunda.org/manual/7.7/introduction/third-party-libraries/.

Third party libraries

The process engine depends on the following third-party libraries:

- MyBatis mapping framework, (Apache License 2.0) for object-relational mapping
- Joda Time, (Apache License 2.0) for parsing date formats
- Java Uuid Generator (JUG), (Apache License 2.0) Id Generator
- SLF4J, (MIT License) Logging Façade
- Apache Commons Email, (Apache License 2.0) for mail task support
- Groovy, (Apache License 2.0) for groovy script task support

The REST API depends on the following third-party libraries:

- Jackson JAX-RS, (Apache License 2.0) provider for JSON content type
- Apache Commons FileUpload, (Apache License 2.0)

Camunda Spin depends on the following third-party libraries:

- Jackson Json, (Apache License 2.0) for Json Dataformat Support

Camunda Connect depends on the following third-party libraries:

- Apache Http Components, (Apache License 2.0) for REST and SOAP support

The Camunda Webapps (Cockpit, Tasklist, Admin) include the following third-party libraries:

- AngularJS, (MIT License)
- AngularUI, (MIT License)
- bpmn-js, (bpmn-js Custom license)
- domReady, (MIT License or new BSD License)
- heatmap.js, (MIT License)
- Placeholder.js, (MIT License)
- prism.js, (MIT License)
- jQuery, (MIT License)
- jQuery UI, (MIT License)
- RequireJS, (MIT License)
- Snap.svg, (Apache License 2.0)
- Twitter Bootstrap, (Apache License 2.0)
- Mousetrap, (Apache License 2.0)

Most of these libraries are used in the Camunda commons UI library which is aimed at easing development of browser based user interfaces.

The Camunda Javascript SDK (including the Forms SDK) integrates with the following third-party libraries:

- Super Agent, (MIT License)
- jQuery, (MIT License)
- AngularJS, (MIT License)
- AngularUI, (MIT License)

The Camunda Modeler includes the following third-party libraries:

- Electron, (MIT License)
- Chromium, (Chromium License Details)
- Node.js, (Node.js License Details)
- CodeMirror, (MIT License)
- Twitter Bootstrap, (MIT License)
- virtual-dom, (MIT License)

Regarding connection to DB server, PostgreSQL is released under the PostgreSQL License, a liberal Open Source license, similar to the BSD or MIT licenses.

2.4.4 Installation Guide

In short, installing MPMS includes the following steps:

Prerequisites

- Before downloading Camunda, make sure you have a JRE (Java Runtime Environment), or better, a JDK (Java Development Kit) installed. It is recommended to use Java 8 unless your container/application server does not support Java 8 (like JBoss Application Server 7). We installed Java 8 (after Java is installed, make sure that "JAVA_HOME" and/or "JRE_HOME" environment variables are set in your system).
- Apache Maven (optional, if not installed you can use embedded Maven e.g. inside Eclipse IDE)

Installation

- Download and install Camunda BPM 7.7.0 – WildFly 10 Distribution
- Download PostgreSQL JDBC Driver for DB integration and put it on a specific folder of Camunda distribution (details below)
- Modify configuration file of Camunda engine ("*standalone.xml*" file of application server)
- Run db scripts to create the "horse" DB and populate initial data (e.g. task definitions, agent definitions, product info, etc.)
- Configure the connection to the Message Bus server in the application process that is implemented by TUE
- Deploy the application process which is responsible to make the process models executable by Camunda engine. This deployment will generate a .war file which needs to be dropped to the deployments folder of the application server (in the downloaded Camunda distribution).
- Run Camunda engine ("start" script file in the downloaded Camunda distribution
- Create any users in Camunda Admin web application and give authorizations (optional)
- Start a process in Camunda Tasklist web application
- Monitor a process in Camunda Cockpit web application

The software, along with configuration scripts, deployment scripts and scripts for inserting data to the DB, as well as supporting documentation (like setting up users of Camunda, and detailed steps for installation) should be requested by TUE (dr.ir. Irene Vanderfeesten at I.T.P.Vanderfeesten@tue.nl).

2.4.5 Administration and support

TUE is responsible for modelling manufacturing processes and making them executable by the MPMS. For more information please contact dr.ir. Irene Vanderfeesten at I.T.P.Vanderfeesten@tue.nl.

2.5 *Situation Awareness*

2.5.1 Short Description

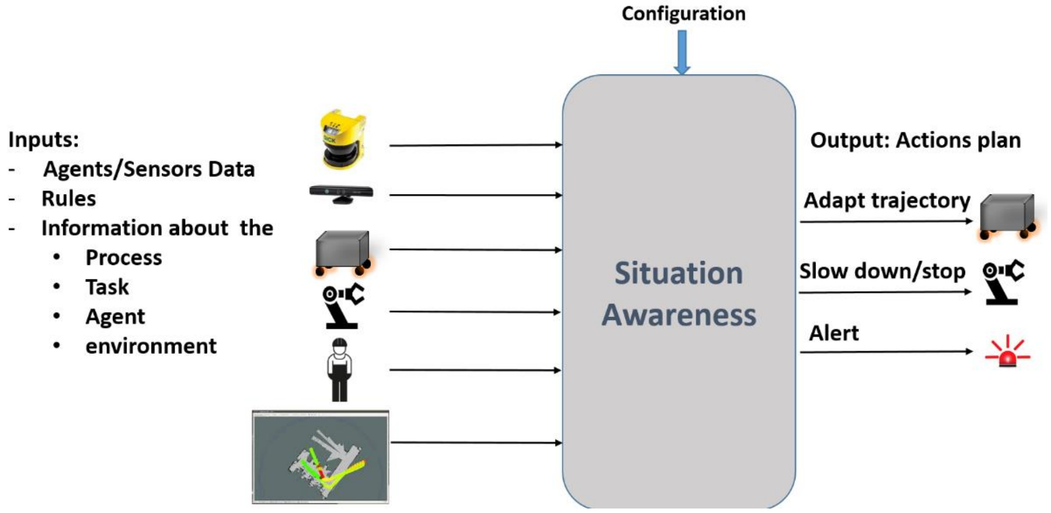


Figure 8: Situation Awareness within HORSE framework

The situation awareness module (Figure 8) is able to detect critical events based on contextual data. This module relies on **a reasoning system** and **a planner** in order to generate a new action plan for the appropriate agents.

Situation Awareness functionality is ensured through different levels of the HORSE framework: local and global. In the local level, when a critical event is raised locally, the event is received and handled by the *Local Safety Guard* which interacts with the agents (human or automated) operating in the current work cell or location. Copies of the local safety alerts are sent to the *Global Safety Guard.* This module processes contextual data originating in the local work cells and can trigger safety or process related operations onto agents operating in other work cells. CEA provides implementation of these two modules. A detailed description is provided in HORSE deliverable D3.6.

The component presented in this chapter can be used at both local and global levels.

2.5.2 System Requirements

In the following, we present the requirements for using our system from a developer perspective and a user perspective.

2.5.2.1 Design and development requirements

Modules and Libraries:

- Eclipse Integrated Development Environment: Eclipse Neon Milestone 6 (4.6.0M6) with the following plugins:
- JavaSE-1.8
- JRE1.8.0_65

- Maven
- Message Pack and MessagePack-RPC libraries[2]
- Protégé[3] ontology editor
- OWL files contain the ontologies including environment and task-specific information
- SWRL files define rules for the reasoner

2.5.2.2 Configuration

The locations ontology has to be populated with geometric data. These data must conform to the geometric data returned by the different actors (i.e. the mobile base and the Kinect in this use case). A world frame must be defined in order to express measures with respect to this frame. In the rest of this section we use O1 (as defined in Figure 9) as the world frame.

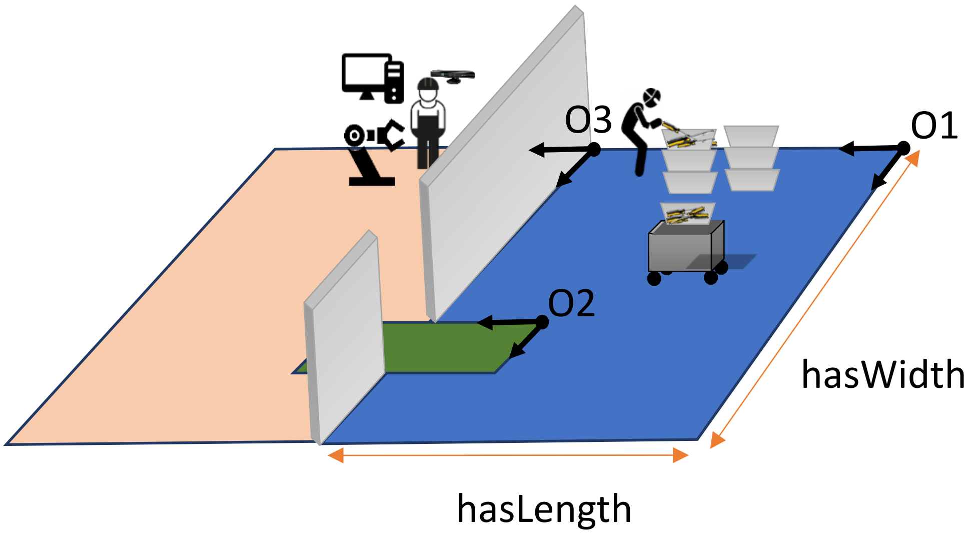


Figure 9: Use case scene

The data about the involved individuals must be filled in in the ontology ("Location2DB.owl"):

- "CartesianPositionOfDoorHallSybotRoom": position of the origin for the door (O2 on the Figure 9). O2 must be expressed in O1 frame.
  - "hasY": origin position along y axis
  - "hasX": origin position along x axis
- "CartesianPositionOfSybotRoom": position of the origin for the room where the robot is located (O3 on the Figure 9). O3 must be expressed in O1 frame.

[2] https://msgpack.org/

[3] https://protege.stanford.edu/

  - "hasY": origin position along y axis
  - "hasX": origin position along x axis
- "CartesianPositionOfOriginOfHall": position of the origin of the room where the operator is located (O1 on the Figure 9): O2 must be expressed in O1 frame.
  - "hasY": origin position along y axis
  - "hasX": origin position along x axis

- "SpatialPositionOfDoorHallSybotRoom": dimension of the area in green on the Figure 9 (it appears bigger than it is on the figure to make it visible)
  - "hasWidth" as on the Figure 9
  - "hasLength" as the Figure 9
- "SpatialPositionOfSybotRoom": dimension of the room in pink on the Figure 9
  - "hasWidth" as on the Figure 9
  - "hasLength" as the Figure 9
- "SpatialPositionOfHall": dimension of the room in blue on the Figure 9
  - "hasWidth" as on the Figure 9
  - "hasLength" as the Figure 9

A set of actions are pre-defined in the actions ontology ("Action2DB.owl"). If used robot differs from the one used for the use case, useful actions must be implemented for the robot (e.g. actions such as "MoveToPosition" or "Stop" for the mobile base). If unlisted actions are required, they must be referenced in the ontology and in the source code of the local situation awareness module.

Other parameters such as the distance thresholds that are used in the rules could be modified in the dedicated xml file. These parameters are:

- "GoalInTheSameRoom" and "GoalNextRoomNearSybot": cartesian positions of the mobile base goals
- "Hidden": cartesian position of the hidden position of the mobile base (safe position to reach when the agent and the mobile base are about to cross the door at the same time)
- "Home": cartesian position for the mobile base (i.e. rest position)
- "isHowCloseToThresholds": distance thresholds that raises different level of warnings

2.5.2.3 Runtime platform

The module is executed as a Java binary. Due to the platform independency of the Java applications, they could be deployed and operated in multiple operating systems. The module has been successfully tested on Windows, Linux and MAC-OS.

- CPU – Intel x386
- OS – Windows/Linux/MAC-OS

- Memory – at least 4 GB
- Disk Space – at least 100 MB
- Java Runtime Environment 1.8+
- Each device requires an implementation embedding MsgPack_RPC server

2.5.3 Legal Status

CEA is the exclusive owner of the intellectual properties on the components developed by its team. Upon a written request, CEA can offer a separate license agreement granting access rights on a non-exclusive basis, without the right to sublicense, and in case of software, in object code. The request for access rights may be made up to twelve months after the end of the project. It should specify the intended purpose.

CEA will transmit the specific conditions that will be applied for the specific access right. The rights will be granted subject to confidentiality obligations. Access Rights shall be granted on a royalty-free basis for the performance of the own work of a party under the Project for the duration of the Project. Access rights shall be granted against financial compensation if needed for exploitation of a party's own results in case of direct or indirect industrial or commercial exploitation.

2.5.4 Installation Guide

The safety guard equipment and software modules are to be requested by CEA. Their installation and configuration should be performed by a CEA professional.

2.5.5 Administration and support

This component can be operated only after a short training provided by CEA. For more information, please contact:

- Romain Farel (Romain.FAREL@cea.fr) or
- Selma Kchir (Selma.KCHIR@cea.fr).

2.6 FlexBE

2.6.1 Short Description

FlexBE is the base component of the HORSE intuitive programming sub-system for robots. It serves as Task Design Interface of the HORSE framework to permit the definition of tasks through a user-friendly graphical interface. This allows the easy definition or modification of a task without the need of a software expert.

2.6.2 System Requirements

FlexBE requires Ubuntu Linux 16.04 with the ROS Kinetic framework.

2.6.3 Legal Status

The *flexbe_behavior_engine* and the *flexbe_app* are distributed under the *BSD* license.

The behaviours and messages packages are distributed under:

2.6.4 Installation Guide

The software and the installation guidelines, as well as an one-click installation script, are available at the HORSE website, under the menu "About HORSE -> Publications".

2.6.5 Administration and support

For help and support contact:

- Gabriele Bolano (bolano@fzi.de)
- Christian Jülg (juelg@fzi.de)

2.7 Augmented Reality

2.7.1 Short Description

The Augmented Reality module provided by TNO is a highly sophisticated HMI. It assists the human operator by performing novel and complex manipulations by projecting step-by-step instructions and other helpful information. The integrated sensors recognise the motions of the operator identifying the adherence to or deviation from the designed workflow. The realisation of the customer specific workflow and operations and the integration of specific instruments require a significant amount of coding and customisation. That's why a one-for-all out of the box solution is not available.

2.7.2 System Requirements

The software is developed and tested with the following system requirements.

- OS: Windows 10, 64 bit.
  Note that it should also be able to work on other Windows versions
- Memory: 16 GB
- Disk Space: 200 GB

The following software modules are required:

- Python 3 (Anaconda 3.4.3.1 version recommended) including several packages
- OPS 3.5.2 Light Guide System software (http://lightguidesys.com/)
- Kinect SDK
- TNO AR software

The following tables from the HORSE DB are used:

- toolingblock,
- taskdef
- arwi
- arbintasks
- bins
- arbin_location

- arwi_graphics (to be used (or similar) in the future)
- arworkstation (to be used (or similar) in the future)

2.7.3 Legal Status

The system modules are distributed under the following licenses:

- OPS (http://lightguidesys.com/)
- Python, anaconda distribution: free software licence

2.7.4 Installation Guide

The AR software itself will be provided as a stand-alone distribution, which will include the python interpreter and all the necessary packages.

The AR software and installers developed for the TRI pilot site can be requested from TNO.

TNO can provide the needed teaching and support for the setup. An overview of the installation steps:

- Install OPS (ver3.5.2), using the provided installer.
- If necessary, install Microsoft XNA Game Studio 3.1
- Install Kinect for Windows SDK 2.0.
- Deploy the AR software and connection to the HORSE framework

2.7.5 Administration and support

The system should be operated only by qualified personnel. For help and support contact:

- Jasper Winters, Technical lead (jasper.winter@tno.nl)
- Sandra Koster, Software engineer (sandra.koster@tno.nl)
- Tim Bosch, OPS/AR work instructions (tim.bosch@tno.nl)

2.8 Local Safety Guard

2.8.1 Short Description

The Local Safety Guard implementation of FZI is based on the Collision Prediction and Prevention modules of the HORSE framework, in order to allow human-robot collaboration in a shared workspace.

This component can be used in every use-case that involves the need of a human operator into the robot workspace, in order to avoid collisions and guarantee better efficiency fostering the robot to work in areas away from obstacles.

2.8.2 System Requirements

The software has been tested with the following system configuration:

- Ubuntu Linux 16.04
- CUDA 7.5, 8.0, 9.1 Toolkit
- ROS Kinetic framework

Cuda 8.0: using Cuda 8.0 code needed to be compiled with older GPU drivers such as 375.66, since there are compatibility issues with driver 384.111 and newer.

The main software component of the system is the GPU-Voxels library.

To permit a correct collision detection with the live environment, the sub-system requires a ROS URDF description of the environment and of the robot collision model. This model is used to compute the swept volumes of any robot trajectory. These volumes can then be used for online collision checking.

The hardware requirements are a CUDA-compatible GPU and any ROS-compatible 3D camera. The cameras need to be calibrated to have the correct pose of the live environment data in the reference frame in relation to the robot.

2.8.3 Legal Status

The *GPU-Voxels* library is distributed under the *CDDL* license.

The Local Safety Guard component consists also of packages distributed under:

2.8.4 Installation Guide

The software and the installation guidelines are available at the HORSE website, under the menu "About HORSE -> Publications".

2.8.5 Administration and support

For help and support contact:

- Gabriele Bolano (bolano@fzi.de)
- Christian Jülg (juelg@fzi.de)

2.9 Human Detection and Tracking

2.9.1 Short Description

The Human Detection and Tracking software aggregates data from multiple sensor data processing modules and verifies if any of them detected a human intrusion to the robots workspace. It allows the definition of three types of areas: safe (a human is allowed to be here), danger (robot slows down when entered) and stop.

So far, modules for connecting three different types of sensors are provided:

- Depth Cameras
- Pressure Sensitive Floor
- 2d laser range finders

2.9.2 System Requirements

OS:	Linux (reconmended Ubuntu 16.04)
Memory:	Depends on the used sensor modules
Disk Space:	around 3GB for a full ROS installation

2.9.3 Legal Status

The component is provided free of charge for use in the time frame of the HORSE project by the HORSE partners and participants of HORSE Open Calls.

For use after the project end, please contact TU Munich (see the contact in Section 2.9.5 Administration and support)

2.9.4 Installation Guide

Please note: all steps below are supposed to be executed by an operator / programmer experienced in using ROS.

Preparation

If not already installed, ROS could be installed as described in the ROS Wiki (use Desktop-Full Install).

Run apt to install other missing dependencies:

```
sudo apt install ros-kinetic-moveit ros-kinetic-libfreenect ros-kinetic-realtime-tools ros-kinetic-controller-interface ros-kinetic-control-toolbox ros-kinetic-controller-manager ros-kinetic-joint-limits-interface libfreenect-dev libceres-dev
```

For using a Kinect v2 sensor it is necessary to build and install libfreenect2 from source. See the Libfreenect-Wiki for instructions.

Set up a URDF description of your (physical) workspace with your sensor positions and orientations.

Setup

Add the files you received from TUM to your catkin workspace and run catkin_make

Adjust the config files according to your sensor calibration data.

Run the launch file provided by TUM.

2.9.5 Administration and support

For help and support contact:

- Arne Peters (arne.peters@tum.de)
- Michael Zechmair (michael.zechmair@in.tum.de)

2.10 Deviation Monitor

2.10.1 Short Description

The Deviation Monitor component is responsible to monitor the low level signals related to the work-cell. These signals could be the joint position of the robot or the distance data acquired from a range laser sensor. The component allows to detect anomalies based on thresholds obtained through a learning phase or specified by the user.

2.10.2 System Requirements

The system requirements are the following:

- Ubuntu Linux 16.04
- ROS Kinetic framework

2.10.3 Legal Status

The Deviation Monitor component is distributed under:

(c) Copyright 2015-2018 FZI Forschungszentrum Informatik, Karlsruhe, Germany

All rights reserved.

2.10.4 Installation Guide

The software and the installation guidelines are available at the HORSE website, under the menu "About HORSE -> Publications".

2.10.5 Administration and support

For help and support contact:

- Gabriele Bolano (bolano@fzi.de)
- Christian Jülg (juelg@fzi.de)

2.11 Agent Manager

2.11.1 Short Description

The HORSE Agent Manager is a functional module that is distributed as part of the HORSE Broker. It is started automatically when the Broker is started.

2.11.2 System Requirements

As for the HORSE Broker

2.11.3 Legal Status

As for the HORSE Broker

2.11.4 Installation Guide

As for the HORSE Broker

2.11.5 Administration and support

As for the HORSE Broker

2.12 BOS Adapter

2.12.1 Short Description

The BOS Adapter is a group of bundles enabling the communication of the HORSE components (over HORSE Messaging Middleware) and the industrial equipment in the factory of Bosch Castellet, Spain.

The BOS adapter sub-modules provide (partial, only what is needed for the project) support for several industrial protocols and interact with diverse types of equipment. This module is provided as a blueprint of automated agent interface.

Figure 10 depicts the architecture of this component and the integrated industrial equipment:

- EtherCAT Interface for interaction with the ATMO2 VisualControl system – triggering taking of snapshots of the checked products and obtaining the inspection results and images ;
- PLC/DDL Interface processing notification events coming from the conveyor belt;
- OPC-UA Interface for switching of a notification beacon (visual signal) when assistance is needed;
- Messaging Agent providing the integration with the HORSE Messaging Middleware;
- Coordinator processing the HORSE messages into invocation of operations through the industrial interfaces and sharing the alerts received through these interfaces as HORSE messages (with main counterpart FlexBe as implementation of the Hybrid Task Supervisor).

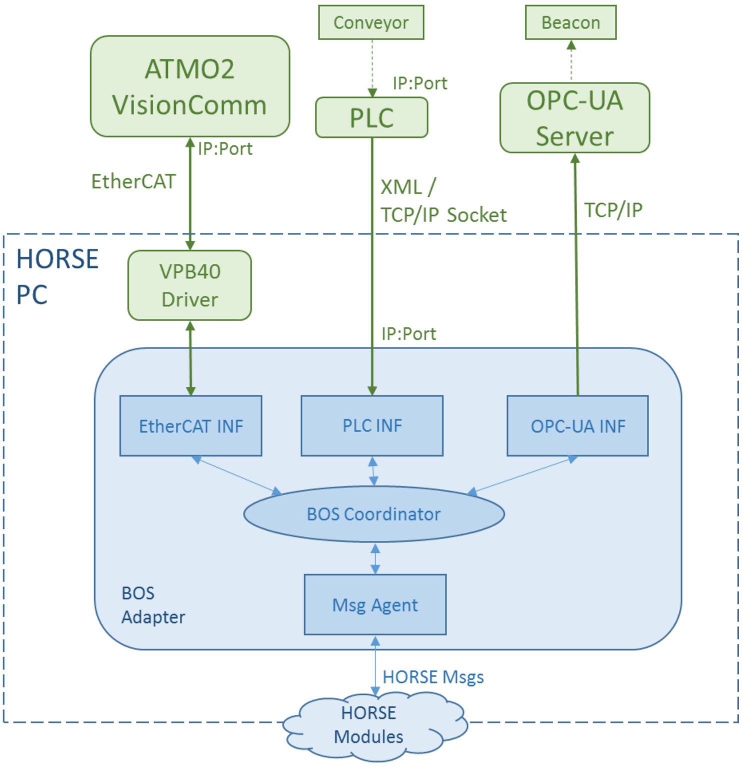


Figure 10: BOS Adapter Architecture

2.12.2 System Requirements

Desktop PC with Beckhoff F9002 etherCAT master card

Linux OS (e.g. Ubuntu 16.04) for the native EtherCAT libraries

2.12.3 Legal Status

The following open source libraries have been used in the module:

- org.eclipse.jetty-io-9.3.0 under Apache 2.0 license
- org.eclipse.jetty-util-9.3.0 under Apache 2.0 license
- org.eclipse.jetty.websocket-api-9.3.0 under Apache 2.0 license
- org.eclipse.jetty.websocket-client-9.3.0 under Apache 2.0 license
- org.eclipse.jetty.websocket-common-9.3.0 under Apache 2.0 license
- gnu.io under LGPL v 2.1 license
- us.ihmc under Apache 2.0 license
- org.postgis under LGPL 2.1 license
- org.postgresql under BSD 2-clause

2.12.4 Installation Guide

- Check Appendix B

2.12.5 Administration and support

The configuration of sub-components is visualised in Appendix B. After the establishment of communication with the external components (HORSE Broker) and systems (PLC, EtherCAT), no additional administration is needed.

For further assistance contact:
Bosch Software Innovations GmbH,
Venelin Arnaudov (Venelin.Arnaudov@bosch-si.com)

2.13 KUKA Sunrise

2.13.1 Short Description

KUKA Sunrise.OS is the system software for the KUKA LBR iiwa robot and other KUKA mobility products like the KMR iiwa . It provides all the functions required for the operation of lightweight robots. Based on Java, Sunrise.Workbench is the programming interface for the robots and mobility products.

For the needs of HORSE project the KUKA Sunrise has been extended with two adapters for handling ROS and HORSE Messaging Middleware messages.

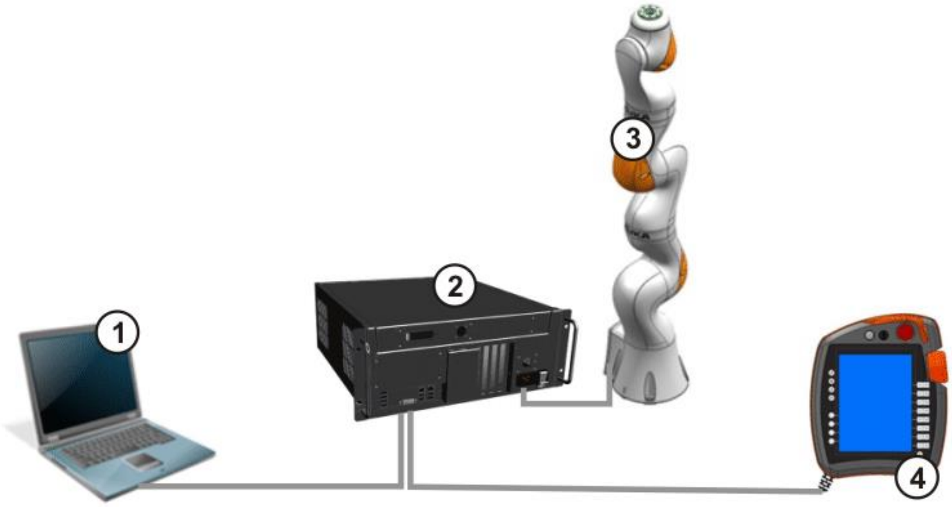


Figure 11: Separation of operator control and programming

1. Development computer with KUKA Sunrise.Workbench (connection via the KLI of the robot controller)
2. KUKA Sunrise Cabinet robot controller
3. Manipulator
4. KUKA smartPAD control panel

2.13.2 System Requirements

For Sunrise.Workbench v1.13

OS: Windows 7

Memory: 2GB RAM

Disk Space: 1GB

Additional software: KUKA Workvisual 4.0 for bus configuration.

2.13.3 Legal Status

KUKA Sunrise.OS uses open-source software. The license terms are stored in the **licenses** folder in the installation directory of KUKA Sunrise.Workbench.
Further information about open-source licenses can be requested from the following address: opensource@kuka.com

KUKA Roboter GmbH
Zugspitzstraße 140
D-86165 Augsburg

Germany

2.13.4 Installation Guide

2.13.4.1 Installing Sunrise.Workbench

Preparation
If an older version of Sunrise.Workbench is already installed:
Uninstall the old version first.

Precondition
Local administrator rights

Procedure

1. Start the program **SunriseWorkbench-[...]-Setup.exe**. A window opens.
2. Select the language for the installation procedure and confirm with **OK**. The language selection only applies to the installation and not to Sunrise.Workbench itself. The default user interface language for Sunrise.Workbench is German.
3. An installation wizard opens. Follow the instructions in the wizard.

2.13.4.2 Starting Sunrise.Workbench

Procedure

1. Double-click on the **Sunrise.Workbench** icon on the desktop.
   Alternative:
   In the Windows Start menu, open the installation directory and doubleclick on **Sunrise Workbench**. The **Workspace Launcher** window opens.
2. In the **Workspace** box, specify the directory for the workspace in which projects are to be saved.
   - A default directory is suggested. The directory can be changed by clicking on the **Browse...** button.
   - If the workspace should not be queried the next time Sunrise.Workbench is started, activate the option **Use this as the default value[...]** (set check mark). Confirm the settings with **OK**.
3. A welcome screen opens the first time Sunrise.Workbench is started. There are different options here.
4. Click on **Workbench** to open the user interface of Sunrise.Workbench

2.13.5 Administration and support

For further assistance, please contact your local KUKA subsidiary:

Germany:
KUKA Roboter GmbH
Zugspitzstr. 140
86165 Augsburg
Germany
Tel. +49 821 797-1926
Fax +49 821 797-41 1926
Hotline.robotics.de@kuka.com
www.kuka-roboter.de

France:
KUKA Automatisme + Robotique SAS
Techvallée
6, Avenue du Parc
91140 Villebon S/Yvette
France
Tel. +33 1 6931660-0
Fax +33 1 6931660-1
commercial@kuka.fr
www.kuka.fr

Poland :
KUKA Roboter CEE GmbH Poland
Spółka z ograniczoną odpowiedzialnością
Oddział w Polsce
Ul. Porcelanowa 10
40-246 Katowice
Poland
Tel. +48 327 30 32 13 or -14
Fax +48 327 30 32 26
ServicePL@kuka-roboter.de

Spain :
KUKA Robots IBÉRICA, S.A.
Pol. Industrial
Torrent de la Pastera
Carrer del Bages s/n
08800 Vilanova i la Geltrú (Barcelona)
Spain
Tel. +34 93 8142-353
Fax +34 93 8142-950
comercial@kukarob.es
www.kuka.es

2.14 iiwa_stack

2.14.1 Short Description

iiwa_stack is a compilation of ROS modules that intgrate KUKA Sunrise with ROS. It provides URDF models for KUKA iiwa LBR 7 and 14 with standard media flange and media flange touch models and is fully integrated with MoveIt!.

Heart of this software is a RosJava node, running directly on the Sunrise Cabinet. In addition to the exiting MoveIt! Interface, we extended RosJava with support of ROS actions and TF to provide an ROS API for common robot motions (Cartesian and joint motions) so that we can program the robot with industrial grade speed and safety settings.

Last but not least we implemented FlexBe states for both MoveIt! and Sunrise based motions..

2.14.2 System Requirements

KUKA LBR iiwa with Sunrise 1.13. Other versions from 1.11 might work as well but have not been tested.

PC with Ubuntu 16.04 and ROS Kinetic.

2.14.3 Legal status

Our contributions to RosJava have been merged to official RosJava packages.

rosjava_tf package is open source and can be found at https://github.com/exo-core/rosjava_tf

iiwa_stack is based on the previous works of Salvatore Virga (TUM) and Marco Esposito (TUM): https://github.com/IFL-CAMP/iiwa_stack. Our extensions can be found at https://github.com/exo-core/iiwa_stack. It is available under BSD license.

2.14.4 Installation guide

See https://github.com/IFL-CAMP/iiwa_stack/wiki for installation instructions.

2.14.5 Administration and support

For help and support contact:

- Arne Peters (arne.peters@tum.de)
- iiwa_stack development page: https://github.com/IFL-CAMP/iiwa_stack/issues and https://github.com/exo-core/iiwa_stack/issues

2.15 Databases

The persistent data used by the HORSE modules is stored in a postgreSQL RDBMS.

The setup of database server is done through a script.

The database configuration and data are stored in a clone of an internal HORSE DB repository. This allows easy maintenance of backups (in the cloud repository). The cloning of the backup data on a new platform acts as creation and population of the tables and data.

For further information and access to the scripts contact:

European Dynamics

Kostas Vasilakis (Kostas.Vasilakis@eurodyn.com)

3 Reference

AngularJS	http://angularjs.org/
AngularUI	http://angular-ui.github.io/
Apache 2.0 License	https://www.apache.org/licenses/LICENSE-2.0
Apache Commons Email	http://commons.apache.org/proper/commons-email/
Apache Commons FileUpload	http://commons.apache.org/proper/commons-fileupload/
Apache Http Components	http://wiki.fasterxml.com/JacksonHome
bpmn-js License	https://raw.githubusercontent.com/bpmn-io/bower-bpmn-js/v0.5.1/LICENSE
bpmn-js	http://bpmn.io/
BSD 2-clause	https://opensource.org/licenses/BSD-2-Clause
Camunda commons UI	http://camunda.github.io/camunda-commons-ui/
CDDL License	https://opensource.org/licenses/CDDL-1.0
Chromium License	https://www.chromium.org/chromium-os/licenses
Chromium	https://www.chromium.org/
CodeMirror	https://codemirror.net/
domReady License	https://raw.githubusercontent.com/requirejs/domReady/master/LICENSE
domReady	https://github.com/requirejs/domReady
Electron	http://electron.atom.io/
Groovy	http://groovy.codehaus.org/
heatmap.js	https://github.com/pa7/heatmap.js
HORSE D2.2.	http://www.horse-project.eu/sites/default/files/publications/HORSE-D2.2%20(Public%20Version).pdf
Jackson JAX-RS	http://wiki.fasterxml.com/JacksonHome
Jackson Json	http://wiki.fasterxml.com/JacksonHome
Java Uuid Generator	http://wiki.fasterxml.com/JugHome
Joda Time	http://www.joda.org/joda-time/
jQuery UI	https://jqueryui.com/
jQuery	http://jquery.com/
JSR 356	https://www.oracle.com/technetwork/articles/java/jsr356-1937161.html
LGPL v2.1	https://www.gnu.org/licenses/old-licenses/lgpl-2.1.en.html
Libfreenect-Wiki	http://wiki.ros.org/libfreenect
MIT License	https://opensource.org/licenses/MIT
Mousetrap	https://github.com/ccampbell/mousetrap

MyBatis mapping framework	http://www.mybatis.org/mybatis-3/
Node.js License	https://github.com/nodejs/node/blob/master/LICENSE
Node.js	https://nodejs.org/en/
OSGi	https://www.osgi.org/
Placeholder.js	https://github.com/jamesallardice/Placeholders.js
PostgreSQL	https://www.postgresql.org/
PostgreSQL JDBC Driver	https://jdbc.postgresql.org/download.html
PostgreSQL License	https://www.opensource.org/licenses/postgresql
prism.js	https://github.com/PrismJS/prism
RequireJS	http://requirejs.org/
ROS Wiki	http://wiki.ros.org/
SLF4J	https://www.slf4j.org/
Snap.svg	http://snapsvg.io/
Super Agent	https://github.com/visionmedia/superagent
Twitter Bootstrap	http://getbootstrap.com/
Twitter Bootstrap	http://getbootstrap.com/
virtual-dom	https://github.com/Matt-Esch/virtual-dom

Appendix A

HORSE Messaging Middleware

Installation and Usage Guide

1. Introduction

The HORSE Message Middleware is meant to deliver messages across clients, using a common message syntax and a central unit that distributes the messages to the receivers. The terms “clients” or “messaging clients” will be used to refer to the senders/receivers of the messages as "agents", while the term “broker” denotes the centralized unit processing the messages and performing their forwarding..

This article is a guide to how to deploy, configure and operate the message bus on both sides - the agent (client) and the server (broker).

The components of the messaging middleware (dispatcher, broker and agent) are available as set of OSGi bundles running on the OSGi Framework implementation, provided by Bosch Software Innovations GmbH (former ProSyst Software GmbH, abbreviated as PRO in the HORSE project), the Bosch IoT Gateway Software (former ProSyst mBedded Server or **mBS**).

2. Setup

a. Download

The binaries of the messaging modules should be requested by Bosch Software Innovations (Venelin Arnaudov, Venelin.Arnaudov@bosch-si.com)

ZIP files

The binaries of the messaging middleware components are organised in the groups and distributed as ZIP files as follows:

- horse-mw-core_YYYYMMDD.zip – the mBS image tailored for HORSE. It is necessary in order to execute the software components developed in the project.
- horse-mw-broker_YYYYMMDD.zip – the Broker binaries and scripts implemented in the scope of the project.
- horse-mw-dispatcher_YYYYMMDD.zip - the Dispatcher binaries and scripts implemented in the scope of the project.
- horse-mw-agent_YYYYMMDD.zip - the binaries and scripts of the reference implementation of the HORSE Messaging Client.

The latest version of the binaries can be requested by Bosch Software Innovations (Venelin Arnaudov, Venelin.Arnaudov@bosch-si.com)

Extract the core package and the needed component packages (broker, dispatcher or agent).

Blend the content of the “horse-mw” directory in one. The recommended destination of the HORSE binaries in Linux environment is /opt directory. The following directory structure will be produced:

```
/opt/horse-mw
    ├──bin
    │   ├──pscripts
    │   └──vms
    │       └──jdk
    ├──bundles
    │   └──horse
    ├──configs
    ├──docs
    ├──lib
    │   ├──framework
    │   │   └──runtimes
    │   │       ├──linux-x86-generic
    │   │       ├──linux-x86_64-generic
    │   │       ├──win-x86
    │   │       └──win-x86_64
    │   └──mbprofiler-agent
    │       └──runtimes
    │           ├──linux-x86-generic
    │           ├──linux-x86_64-generic
    │           ├──win-x86
    │           └──win-x86_64
    └──www
```

Figure 12: File Structure of HORSE Messaging Middleware

The above listed files and Info on the Python Messagebus Client should be requested by Bosch Software Innovations (Venelin Arnaudov, Venelin.Arnaudov@bosch-si.com)

b. Starting the mBS image

After obtaining the binaries, start server.bat (Windows) or server.sh (Linux) from /opt/horse-mw/bin/vms/jdk/ folder. Make sure to make the Linux script executable. (In order to start the mBS in background mode in Linux, start bg_server.sh instead.) The mBS command console will be open.

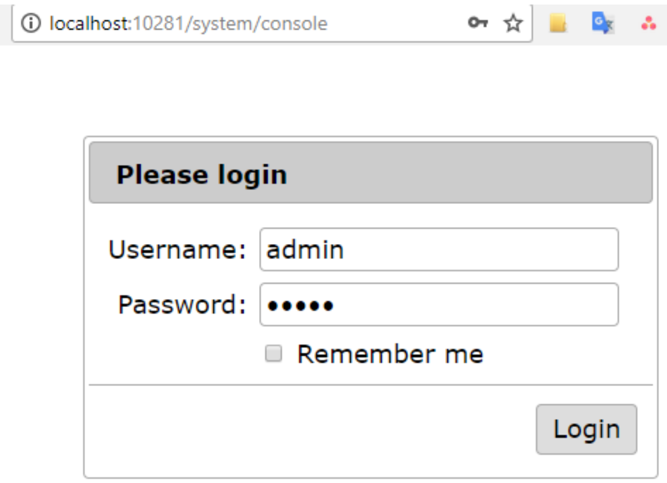
c. Administration tools

The mBS could be managed over the command console or the web console. The latter should be accessible at:
http://<host>:10281/system/console/

Important note!

The given port number of the plain HTTP service is specifically set for HORSE project. The parameters determining the values of the HTTP ports could be changed before the mBS start. This is done by updating the ./configs/ mbs.http.plain.xml file. Deleting or renaming this file will cause the mBS to try to use default ports (primary 80 and secondary 8080). If these ports are not available, no administration over WebAdmin Console will be possible!

The default user name and password for the web console are „admin“ & „admin“.



localhost:10281/system/console

Please login

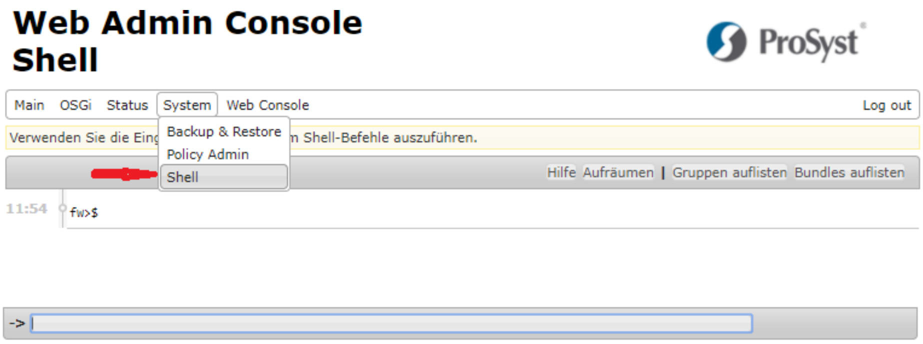
Username: admin

Password: •••••

□ Remember me

Figure 13: WebAdmin Console login

The shell console of the mBS is available through the WebAdmin Console too (via System menu). The commands are to be given at the bottom field. The output will be given on the upper part of the screen under the menu bar.



Web Admin Console
Shell

Verwenden Sie die Eing n Shell-Befehle auszuführen.

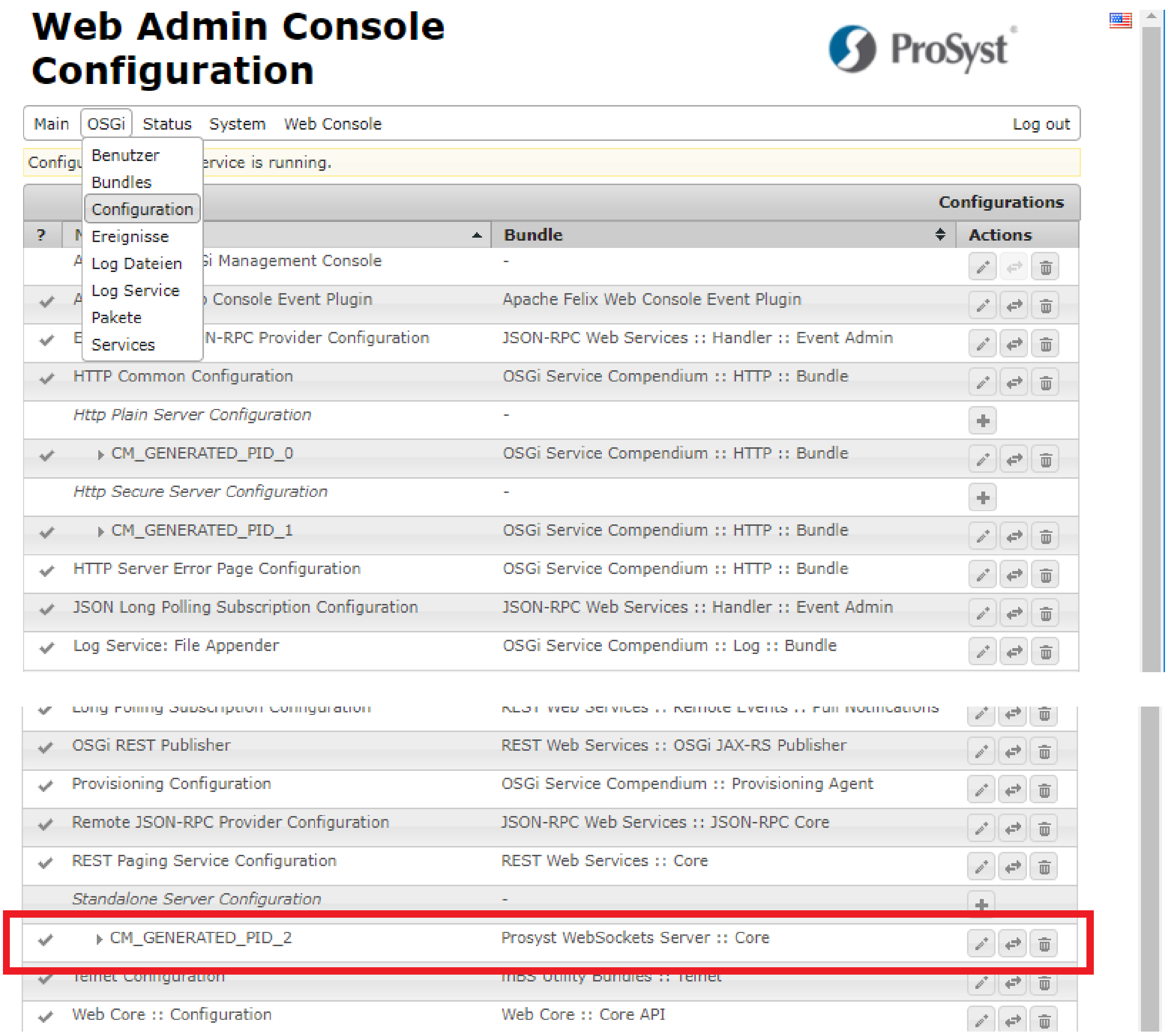
```
11:54 fw>$
```

Figure 14: Access to the shell console

When the mBS is started as a background process (Linux), there is no terminal console. In this case the command console is available only via the WebAdmin.

d. Configuration of the Websockets server

To set the correct port of the websockets server open the Configurations page from OSGi menu of the WebAdmin console.



Web Admin Console Configuration

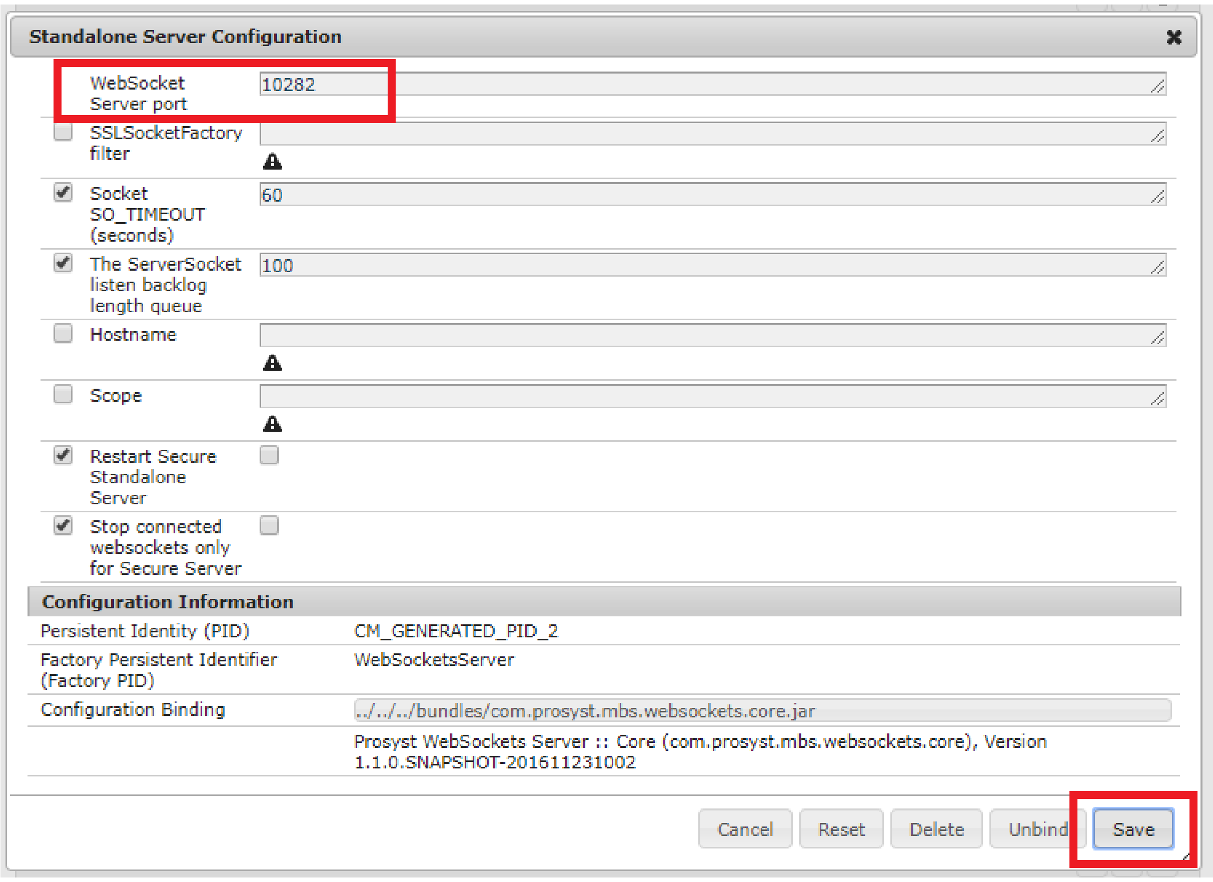
Configu... ervice is running.

Configurations

?	N...	Bundle	Actions
	A... i Management Console	-	
✓	A... Console Event Plugin	Apache Felix Web Console Event Plugin	
✓	E... N-RPC Provider Configuration	JSON-RPC Web Services :: Handler :: Event Admin	
✓	HTTP Common Configuration	OSGi Service Compendium :: HTTP :: Bundle	
	Http Plain Server Configuration	-	+
✓	▸ CM_GENERATED_PID_0	OSGi Service Compendium :: HTTP :: Bundle	
	Http Secure Server Configuration	-	+
✓	▸ CM_GENERATED_PID_1	OSGi Service Compendium :: HTTP :: Bundle	
✓	HTTP Server Error Page Configuration	OSGi Service Compendium :: HTTP :: Bundle	
✓	JSON Long Polling Subscription Configuration	JSON-RPC Web Services :: Handler :: Event Admin	
✓	Log Service: File Appender	OSGi Service Compendium :: Log :: Bundle	
✓	Long Polling Subscription Configuration	REST Web Services :: Remote Events :: Pull Notifications	
✓	OSGi REST Publisher	REST Web Services :: OSGi JAX-RS Publisher	
✓	Provisioning Configuration	OSGi Service Compendium :: Provisioning Agent	
✓	Remote JSON-RPC Provider Configuration	JSON-RPC Web Services :: JSON-RPC Core	
✓	REST Paging Service Configuration	REST Web Services :: Core	
	Standalone Server Configuration	-	+
✓	▸ CM_GENERATED_PID_2	Prosyst WebSockets Server :: Core	
✓	Telnet Configuration	mBS Utility Bundles :: Telnet	
✓	Web Core :: Configuration	Web Core :: Core API	

Figure 15: Configurations list

Navigate to „Prosyst Websockets Server :: Core“ and click to open the configuration.



Standalone Server Configuration ✖

	WebSocket Server port	10282
☐	SSLSocketFactory filter	⚠
☑	Socket SO_TIMEOUT (seconds)	60
☑	The ServerSocket listen backlog length queue	100
☐	Hostname	⚠
☐	Scope	⚠
☑	Restart Secure Standalone Server	☐
☑	Stop connected websockets only for Secure Server	☐

Configuration Information

Persistent Identity (PID)	CM_GENERATED_PID_2
Factory Persistent Identifier (Factory PID)	WebSocketsServer
Configuration Binding	../../../bundles/com.prosyst.mbs.websockets.core.jar
	Prosyst WebSockets Server :: Core (com.prosyst.mbs.websockets.core), Version 1.1.0.SNAPSHOT-201611231002

Figure 16: Websockets server configuration

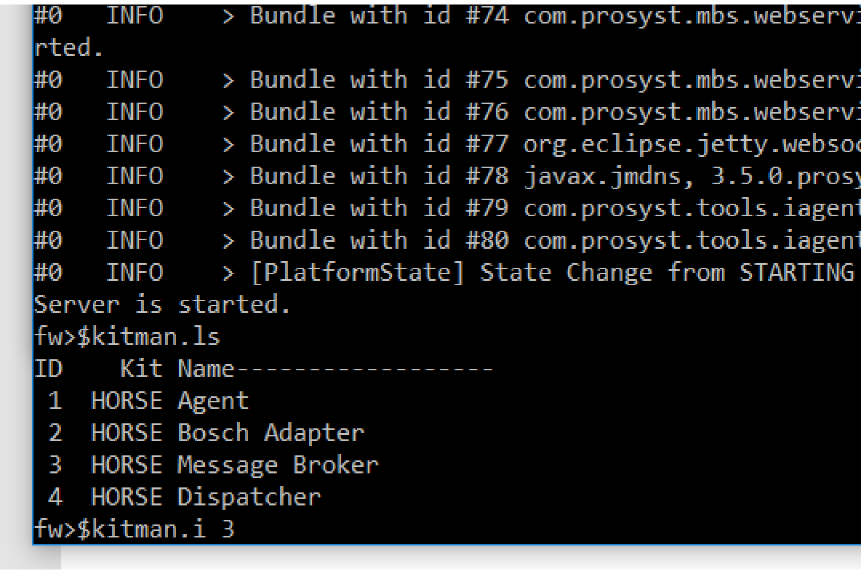
Provide the correct port (the agreed port for HORSE broker is 10282) and save the configuration.

e. Installation of the needed components

As mentioned above, the ZIP archive contains the components (OSGi bundles) for several HORSE applications. The installation of the needed set of bundles is managed by script commands.

Execute the console command “kitman.ls” to get the list of available scripts.

Execute the console command “kitman.i “ plus the number of the script in order to install its components.



```
#0   INFO    > Bundle with id #74 com.prosyst.mbs.webservi
rted.
#0   INFO    > Bundle with id #75 com.prosyst.mbs.webservi
#0   INFO    > Bundle with id #76 com.prosyst.mbs.webservi
#0   INFO    > Bundle with id #77 org.eclipse.jetty.websoc
#0   INFO    > Bundle with id #78 javax.jmdns, 3.5.0.prosy
#0   INFO    > Bundle with id #79 com.prosyst.tools.iagent
#0   INFO    > Bundle with id #80 com.prosyst.tools.iagent
#0   INFO    > [PlatformState] State Change from STARTING
Server is started.
fw>$kitman.ls
ID    Kit Name------------------
 1  HORSE Agent
 2  HORSE Bosch Adapter
 3  HORSE Message Broker
 4  HORSE Dispatcher
fw>$kitman.i 3
```

Figure 17: Kitman scripts

The same commands can be executed via the WebAdmin console shell (Figure 14).

Once the HORSE Message Broker is installed, it could be accessed on the following URI:

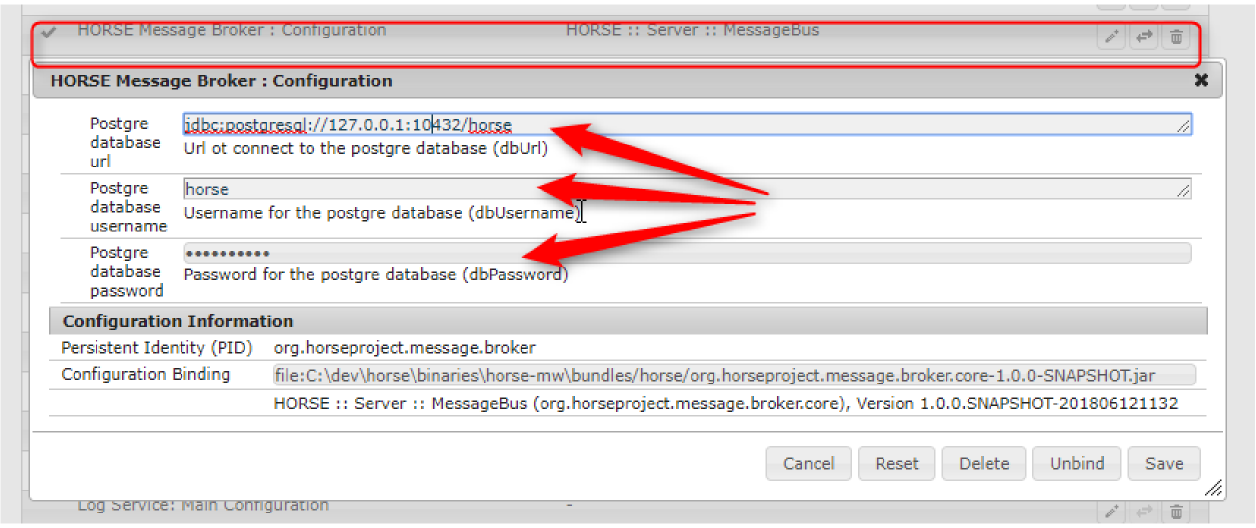
ws:\\<host>:<port>,

where the “host” is the IP or name of the host machine and “port” is the selected websockets server port (e.g. 10282).

f. Configuring the Broker

The proper operation of the Broker requires the correct configuration of the connection to the history database. The configuration panel is accessbilbe from the OSGi/Configuration submenu of the Web Admin Console (see Figure 15)

Upon starting the module, it creates (if not existing) the table “MESSAGE” for storing copies of all received messages.


HORSE Message Broker : Configuration
HORSE :: Server :: MessageBus
HORSE Message Broker : Configuration

Postgre database url: jdbc:postgresql://127.0.0.1:10432/horse
Url ot connect to the postgre database (dbUrl)

Postgre database username: horse
Username for the postgre database (dbUsername)

Postgre database password: ••••••••••
Password for the postgre database (dbPassword)

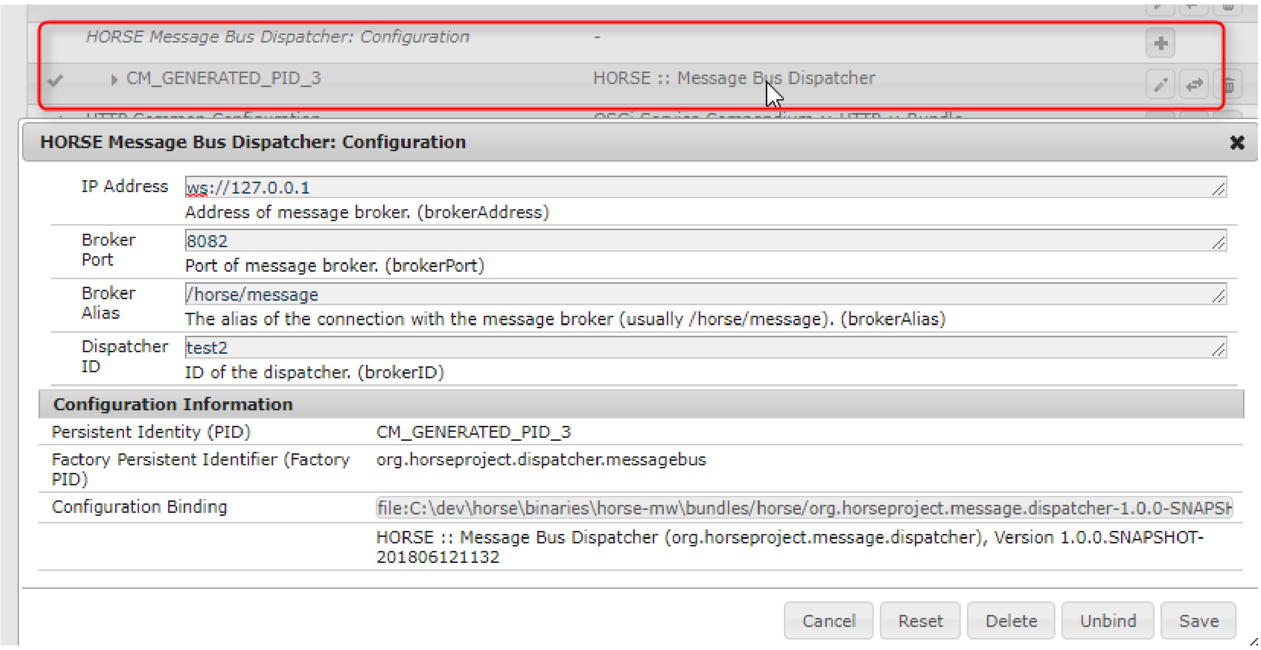
Configuration Information

Persistent Identity (PID)	org.horseproject.message.broker
Configuration Binding	file:C:\dev\horse\binaries\horse-mw\bundles/horse/org.horseproject.message.broker.core-1.0.0-SNAPSHOT.jar
	HORSE :: Server :: MessageBus (org.horseproject.message.broker.core), Version 1.0.0.SNAPSHOT-201806121132

Figure 18: HORSE Broker Configuration

g. Configuration of the Dispatcher

As the Dispatcher is mediating multiple Brokers, it should register itself to each of them as a messaging agent. The parameters of these registrations are provided as configurations as shown in Figure 19.


HORSE Message Bus Dispatcher: Configuration
CM_GENERATED_PID_3
HORSE :: Message Bus Dispatcher
HORSE Message Bus Dispatcher: Configuration

IP Address: ws://127.0.0.1
Address of message broker. (brokerAddress)

Broker Port: 8082
Port of message broker. (brokerPort)

Broker Alias: /horse/message
The alias of the connection with the message broker (usually /horse/message). (brokerAlias)

Dispatcher ID: test2
ID of the dispatcher. (brokerID)

Configuration Information

Persistent Identity (PID)	CM_GENERATED_PID_3
Factory Persistent Identifier (Factory PID)	org.horseproject.dispatcher.messagebus
Configuration Binding	file:C:\dev\horse\binaries\horse-mw\bundles/horse/org.horseproject.message.dispatcher-1.0.0-SNAPSH
	HORSE :: Message Bus Dispatcher (org.horseproject.message.dispatcher), Version 1.0.0.SNAPSHOT-201806121132

Figure 19: HORSE Dispatcher Configuration

h. Stop of the mBS

Recommended. Via console command (terminal or web console shell)

Execute “exit” to gracefully stop all running services and ultimately stop the Java process.

In case the graceful shutdown is not possible it is possible to kill the Java process. There is a risk of losing data.

i. Restart the mBS

The standard way to restart the server is to perform a start after the graceful shutdown. The mBS will reload all components and configurations from the previous session (the connections to the websockets clients could be lost).

In case of problems by start or out of some other reasons It is possible to reset the mBS and perform a “clean” start as follows:

- Delete the local storage (./bin/vms/jdk/storage folder). A backup is recommended.
- Also recommended is to back up the previous log files (./bin/vms/jdk/logs folder).
- Start and configure the mBS and its components.

j. Retrieving the log files

The mBS creates and maintains local log files. They are located in the ./bin/vms/jdk/logs folder. They could be retrieved from the file system (scp, ssh…) or via the WebAdmin console (OSGi -> Log files)

3. Working with the Broker

In order to be able to exchange messages between your agent and the Broker, the following steps need to be executed:

- Initiate a connection
- Send a control message to register your agent
- Start sending and receiving payload messages

a. Initiating a connection

You have to open a websocket connection from your websocket client to the websocket server running on the Broker’s mBS ws:\\<host>:<port>, as stated above

The alias for the connection is "/horse/message" (this can be changed and/or discussed)

The ZIP archive contains an image of a HORSE Message Agent. It could be installed using the Kitman scripts on the same or remote host. We have provided a Jetty-based websocket client.

b. Registering the agent

The registration of an agent is done by sending a special type of message to the Broker, the Control message. It is a Json message with the following format

- ___CONTROL___ It is obligatory that the message is prefixed by this special string!
- It is followed by a JSON Object with two mandatory fields:

"ID" bearing the unique name of the agent.

"Operation" with two possible values: "connect" and "disconnect" in order to add or remove the agent from the Broker’s list of agents;

A number of other parameters could be provided, if needed.

Example: ___CONTROL___{"ID":"test1","a":"15","b":"something","Operation":"connect"}

c. Exchanging payload messages

Once the agent is registered by the Broker it can send and receive Json-based payload messages with the following format:

- Topic (can be any String) - default value is empty string ("")
- Priority (from 1 - Lowest to 5 - Highest) - default value is 1 (Lowest)
- Receivers (a comma-separated list of IDs, if a star is included all receivers will get this message) - default value is * (all recipients)
- Type (1 for Debug, 2 for Event, 3 for System, 4 for Custom) - default value is 4 (Custom)
- Timestamp - The timestamp of the initial sending of the message. Long data type; automatically set by first broker the message passes through.
- Subtype (fully customizable, can be any string).
- SenderID - the ID of the sending client. Should be automatically set by all implementations to the sending client.
- MessageID - a timestamp in milliseconds corresponding to a message which wants to be answered back to. Default value is "" (empty string).
- ResponseMessageID - The timestamp of the message of the sender to which we are sending a reply message. This is meant to say that the message we are sending is an answer to a previous message with a specific senderID and messageID. Default value is "" (empty string).
- Internal – if set, this flag sends the message to the agents of the broker which is directly connected (i.e. without connecting to the dispatcher) to the sending client
- ExternalBrokers – If a message is to be sent over the dispatcher, this shows which dispatcher broker this should get sent to. This is a comma-separated list. It corresponds to the ID of the web socket connection between the dispatcher and the corresponding message bus.An asterisk ("*") sends to all brokers.

- SenderBroker – If a message is to be relayed using the dispatcher, this field is normally set by the dispatcher to note the sending message broker. It is also used to protect against looping of a message between the broker and dispatcher.
- The body (payload) can be any JSON Object with proper syntax - default value is empty JSON Object "{}.

Example:

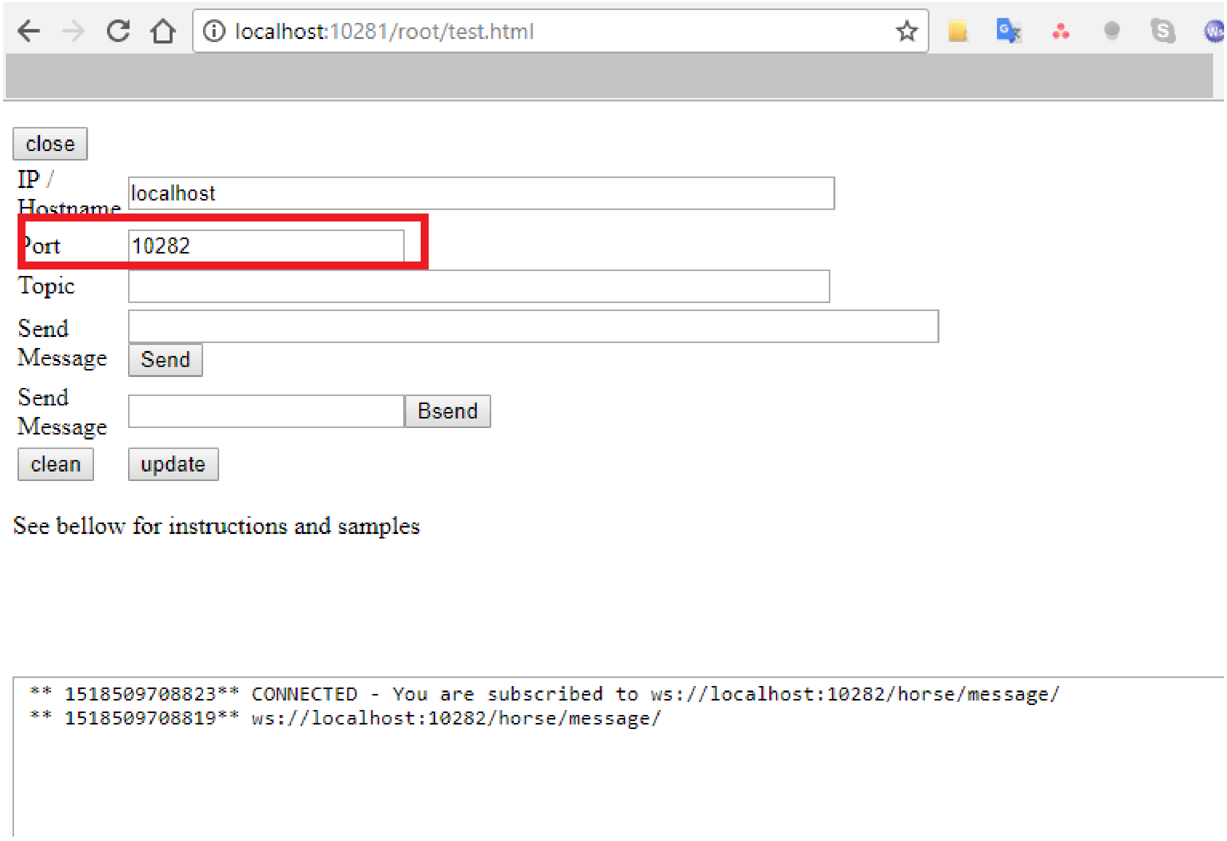
```
{"Topic":"test_domain/topic/something",
"Priority":"1",
"ResponseMessageID":"1234567",
"Receivers":"Test_client_2,something,*",
"SenderID":"dummy_component",
"MessageID":"1484816109871",
"Type":"3",
"Timestamp":"123413412"
"Subtype":"GETAGENTLIST",
"Internal":"true",
"ExternalBrokers":"test_broker_2",
"SenderBroker":"test_broker_1",
"Body":{}}
```

4. Useful tools

We have provided several useful options to simulate and test the HORSE messaging, as well as access the information of the Broker:

a. Web based interface

A test.html file is available at http://<host>:<port>/root/test.html, where the “host” is the host name or ip of the machine running the HORSE messaging component (agent or broker) and “port” is the port of the HTTP server on that machine (e.g. 10281). It has a hard-coded alias of "/horse/message" which can be changed in the HTML file.



localhost

10282

See bellow for instructions and samples

```
** 1518509708823** CONNECTED - You are subscribed to ws://localhost:10282/horse/message/
** 1518509708819** ws://localhost:10282/horse/message/
```

Figure 20: Test web client

Provide the IP address and websocket port of the Broker and click “Update” in order to establish the websockets connection.

An instance of a running Broker is available at the HORSE integration server (vmknoll33.informatik.tu-muenchen.de IP: 131.159.61.234) on port 10282!

Provide the needed topic (for Control messages, not relevant) and message text, and press “Send”

b. Jetty-based interface

The Jetty-based client operates with the following console commands to open and run connections:

horse.create-client (alias: cc) - creates a WebSocket connection with the following parameters:

- Hostname of the messageBus running machine
- port of the WebSocket
- alias, normally this should be always set to the value of "/horse/message"

- newly requested ID (can be any string value)
- a map with all the other parameters of the client, such as {param_1=value_1, param_2=value_2, ….}

horse.list (alias: ls) - lists all active clients <on the side of the client mBS!>

horse.send-message (alias: sm) - sends a message ot the messageBus to redistribute; note that the active client has to have sent a control message to register (i.e. the create-client command has to have had been executed) before this operation can be completed successfully; the parameters are as follows:

- id of the active client to send with (seen with ls command)
- topic of the message
- priority of the message (1-5)
- type of the message (1-4)
- subtype of the message (any string)
- internal flag - if set, sends the message to the internal message broker agents.
- recipients (comma-separated string of values, * for all clients)
- externalBrokers (comma-separated string of values, default value is empty string)
- return flag - if true, the message is sent with an additional JSON Field (MessageID) to denote that it wants to be answered back to
- response message ID of the message
- body (valid JSONObject string)

horse.stop-client (alias : sc) - stops a web socket client with the given ID as argument.

c. Monitoring the connection

There are two ways to monitor which clients have connected (and registered) to the message bus:

via console commands

- horseserver.ls will print information about all clients (server-side!)
- horseserver.reset in case the thread to send messages stops working, normally this isn't needed and is for debugging purposes only
- horseserver.stop-client (alias : sc) - stops a web socket client with the given ID as argument.

via REST at http://<host>:<port>/restdoc/swagger-ui/index.html

- the /horse/ids method is a simple listing mechanism for the used registered IDs of clients (server-side!)
- The /horse/details/{id} method is meant to provide additional information for a specific ID.

4 Appendix B

HORSE BOS Adapter

Installation and Usage Guide

1. Introduction

Since similarly to the HORSE Messaging Middleware components, the BOS Adapter components are distributed as OSGi bundle and executed in the same environment (Bosch IoT Gateway Software, former mBS), this guide will cover only the specific operations.

2. Setup

The BOS Adapter binaries should be requested by Bosch Software Innovations (Venelin Arnaudov, Venelin.Arnaudov@bosch-si.com):

- horse-bos-adapter_YYYYMMDD.zip - the binaries and scripts of the BOS Adapter modules.

Since the BOS Adapter components are executed in the mBS, the **horse-mw-core package**, providing the mBS is required.

The latest version of the BOS Adapter binaries can be requested by Bosch Software Innovations (Venelin Arnaudov, Venelin.Arnaudov@bosch-si.com)

The installation, configuration and start of the mBS is explained in Appendix A.

The installation of the BOS Adapter modules is done by executing kitman commands as shown Section 2.e Installation of the needed components of Appendix A (Figure 17).

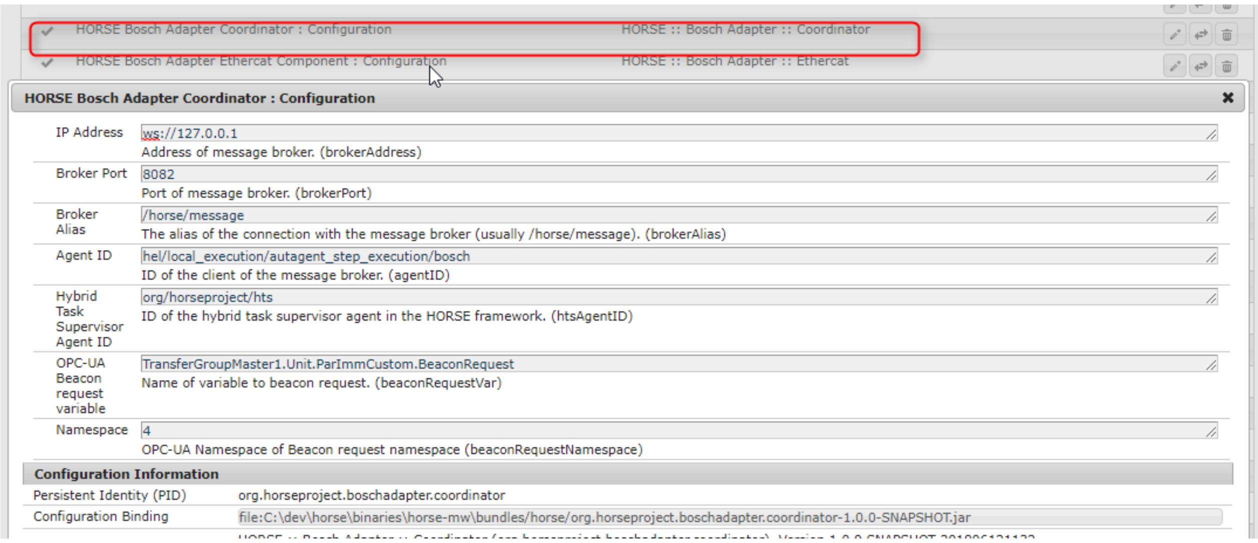
3. Configuration of the BOS Adapter modules

The BOS Adapter features the following modules:

1. org.horseproject.boschadapter.api
2. org.horseproject.boschadapter.plc
3. org.horseproject.boschadapter.ethercat
4. org.horseproject.boschadapter.opc-ua
5. org.horseproject.boschadapter.coordinator

Components 2, 3 and 4 provide interfaces to the industrial protocols PLC, EtherCAT and OPC-UA, while the coordinator (#5) is mediating between the protocol interfaces and the HORSE Messaging Middleware.

The next figures show the configuration forms for each components.



HORSE Bosch Adapter Coordinator : Configuration — HORSE :: Bosch Adapter :: Coordinator

HORSE Bosch Adapter Ethercat Component : Configuration — HORSE :: Bosch Adapter :: Ethercat

HORSE Bosch Adapter Coordinator : Configuration

IP Address: ws://127.0.0.1
Address of message broker. (brokerAddress)

Broker Port: 8082
Port of message broker. (brokerPort)

Broker Alias: /horse/message
The alias of the connection with the message broker (usually /horse/message). (brokerAlias)

Agent ID: hel/local_execution/autagent_step_execution/bosch
ID of the client of the message broker. (agentID)

Hybrid Task Supervisor Agent ID: org/horseproject/hts
ID of the hybrid task supervisor agent in the HORSE framework. (htsAgentID)

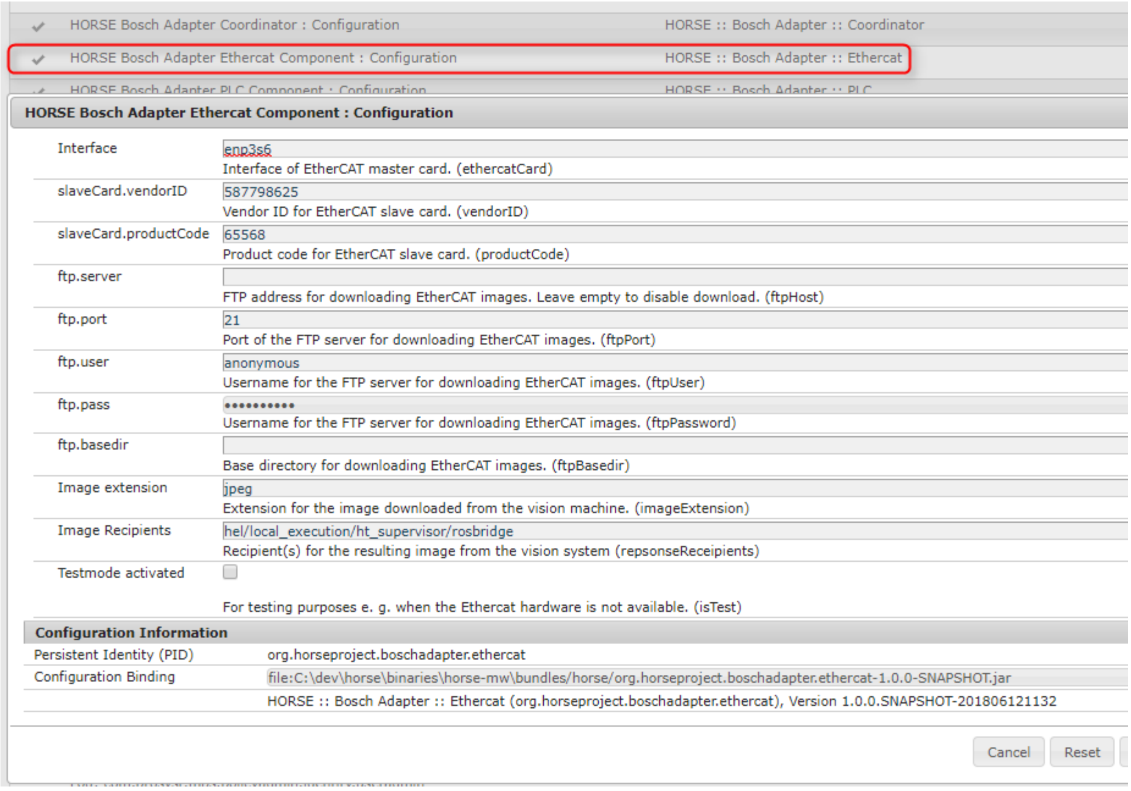
OPC-UA Beacon request variable: TransferGroupMaster1.Unit.ParImmCustom.BeaconRequest
Name of variable to beacon request. (beaconRequestVar)

Namespace: 4
OPC-UA Namespace of Beacon request namespace (beaconRequestNamespace)

Configuration Information

Persistent Identity (PID)	org.horseproject.boschadapter.coordinator
Configuration Binding	file:C:\dev\horse\binaries\horse-mw\bundles/horse/org.horseproject.boschadapter.coordinator-1.0.0-SNAPSHOT.jar

Figure 21: Configuration of the HORSE BOS Adapter - Coordinator



HORSE Bosch Adapter Coordinator : Configuration — HORSE :: Bosch Adapter :: Coordinator

HORSE Bosch Adapter Ethercat Component : Configuration — HORSE :: Bosch Adapter :: Ethercat

HORSE Bosch Adapter PLC Component : Configuration — HORSE :: Bosch Adapter :: PLC

HORSE Bosch Adapter Ethercat Component : Configuration

Interface: enp3s6
Interface of EtherCAT master card. (ethercatCard)

slaveCard.vendorID: 587798625
Vendor ID for EtherCAT slave card. (vendorID)

slaveCard.productCode: 65568
Product code for EtherCAT slave card. (productCode)

ftp.server:
FTP address for downloading EtherCAT images. Leave empty to disable download. (ftpHost)

ftp.port: 21
Port of the FTP server for downloading EtherCAT images. (ftpPort)

ftp.user: anonymous
Username for the FTP server for downloading EtherCAT images. (ftpUser)

ftp.pass: ••••••••••
Username for the FTP server for downloading EtherCAT images. (ftpPassword)

ftp.basedir:
Base directory for downloading EtherCAT images. (ftpBasedir)

Image extension: jpeg
Extension for the image downloaded from the vision machine. (imageExtension)

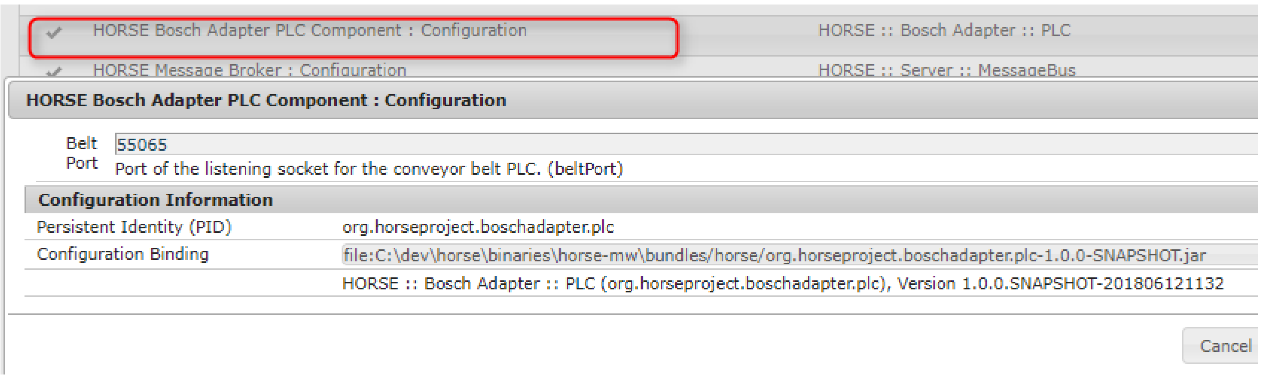
Image Recipients: hel/local_execution/ht_supervisor/rosbridge
Recipient(s) for the resulting image from the vision system (repsonseReceipients)

Testmode activated: □
For testing purposes e. g. when the Ethercat hardware is not available. (isTest)

Configuration Information

Persistent Identity (PID)	org.horseproject.boschadapter.ethercat
Configuration Binding	file:C:\dev\horse\binaries\horse-mw\bundles/horse/org.horseproject.boschadapter.ethercat-1.0.0-SNAPSHOT.jar
	HORSE :: Bosch Adapter :: Ethercat (org.horseproject.boschadapter.ethercat), Version 1.0.0.SNAPSHOT-201806121132

Figure 22: Configuration of HORSE BOS Adapter - EtherCAT Interface



✓ HORSE Bosch Adapter PLC Component : Configuration HORSE :: Bosch Adapter :: PLC

✓ HORSE Message Broker : Configuration HORSE :: Server :: MessageBus

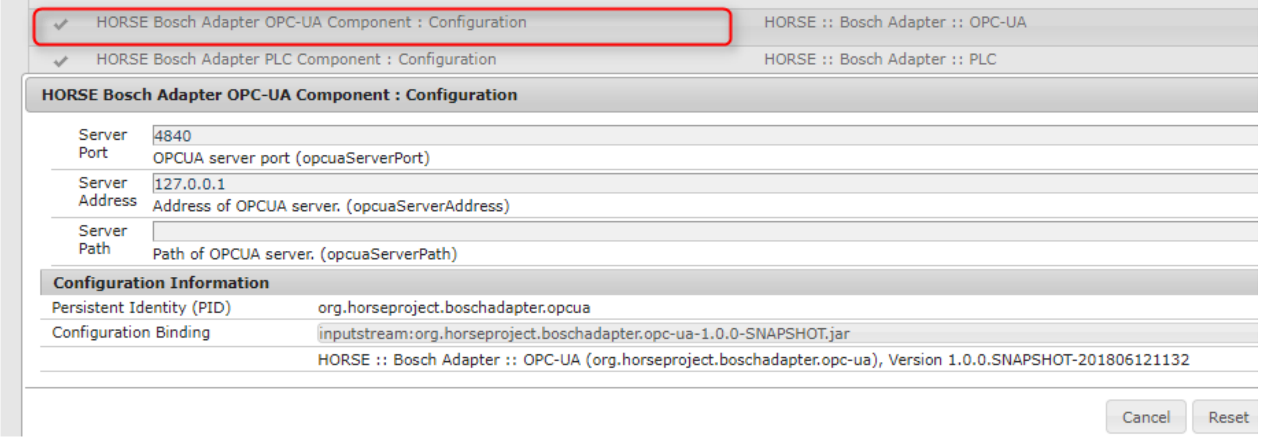
HORSE Bosch Adapter PLC Component : Configuration

Belt Port: 55065
Port of the listening socket for the conveyor belt PLC. (beltPort)

Configuration Information

Persistent Identity (PID)	org.horseproject.boschadapter.plc
Configuration Binding	file:C:\dev\horse\binaries\horse-mw\bundles/horse/org.horseproject.boschadapter.plc-1.0.0-SNAPSHOT.jar
	HORSE :: Bosch Adapter :: PLC (org.horseproject.boschadapter.plc), Version 1.0.0.SNAPSHOT-201806121132

Figure 23: Configuration of HORSE BOS Adapter - PLC Interface



✓ HORSE Bosch Adapter OPC-UA Component : Configuration HORSE :: Bosch Adapter :: OPC-UA

✓ HORSE Bosch Adapter PLC Component : Configuration HORSE :: Bosch Adapter :: PLC

HORSE Bosch Adapter OPC-UA Component : Configuration

Server Port: 4840
OPCUA server port (opcuaServerPort)

Server Address: 127.0.0.1
Address of OPCUA server. (opcuaServerAddress)

Server Path:
Path of OPCUA server. (opcuaServerPath)

Configuration Information

Persistent Identity (PID)	org.horseproject.boschadapter.opcua
Configuration Binding	inputstream:org.horseproject.boschadapter.opc-ua-1.0.0-SNAPSHOT.jar
	HORSE :: Bosch Adapter :: OPC-UA (org.horseproject.boschadapter.opc-ua), Version 1.0.0.SNAPSHOT-201806121132

Figure 24: Configuration of HORSE BOS Adapter - OPC-UA Interface