D2.1-MARIO Services Robots

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Project Number:	**643808**
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D2.1

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Revision history			
Version	**Date**	**Modified by**	**Comments**
1.0	15/07/2015	Meftah Ghrissi	Initial version
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1.5	04/02/2016	Meftah Ghrissi	Review of section 2,4 following Adamantios's review
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1.8	05/07/2016	Meftah Ghrissi	Integration of CNR and IRCCS contributions in table 1
2.0	15/07/2016	Meftah Ghrissi	Add sections 1.4, 5, 6 and review of the document
2.1	19/07/2016	Meftah Ghrissi	Review of Executive Summary
2.2	26/07/2016	Meftah Ghrissi	Answer comments from RUR (sections 4.3 and 4.4)

Executive Summary

This deliverable address the architecture of the MARIO Services Robot with regards to its:

- Mechanical design
- Mechatronic architecture and choice of main components,
- Control system architecture
- Software architecture

This document was revised to answer the reviewers' remarks. The following table indicate page in amended deliverable where these have been addressed:

WP2 - D2.1: Provide a clear description of the technical baseline of the project, including background results from past funded projects where the partners have been participating (such as MOBISERV, DOMEO, iTalk and HOPE), and further explanation regarding the software frameworks and components used for the implementation of the required robot functionalities, such as 3D obstacle detection, posture detection and tracking, and voice recognition (T2.1). [pg 3]	*Robosoft*	*Page 14*
Clearly distinguish between the existing functionalities of the Kompaï robot and the new functionalities of the robot as adapted to the project requirements (T2.1). [pgs 3, 5]	*Robosoft*	Page 17
Further elaborate on the results of tasks T2.2 and T2.3 carried out during this stage of the project since they are insufficiently explained. [pgs 3, 5]	*Passau Ortelio*	Pages 35 and 37
Specify whether the 12 service robots, adapted to the project requirements, have been provided to the project partners as one of the key outcomes of this work package. [pg 3]	*Robosoft*	Page 42
It is also unclear which of the existing software components provided by Robosoft will be used for the required robot functionalities, such as 3D obstacle detection, posture detection and tracking, and voice recognition. [pg 5]	*Robosoft*	Page 41
Milestone 2 (12 Kompai Platform Ready & Iteration Begins): The deliverables do not provide any indication regarding the status and availability of the 12 robotic platforms. Information regarding this milestone was obtained through correspondence with the project coordinator, who informed the reviewers a delay in the availability of the initial two platform and the start of production of the remaining ten platforms. [pg 13]	*Robosoft*	Page 42

This document is the main input to the production process of the robot and to software development partners.

During the design process an iterative study was conducted to confirm the technical choices with regard to mechatronics components and also to avoid potential assembly problems.

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Terminology and abbreviations used

HMI:	Human Machine Interface
PURE:	Professional Universal Robotic Engine
SLAM:	Simultaneous Localization And Mapping

1. Introduction

The key objectives of this work are to describe the hardware and software architecture of MARIO Kompaï robot according to the project requirements and to build the 12 robots needed to assess the project results.

The key outcome from this work is to have 12 robots which conform to the project requirements and are ready to receive software from other partners.

1.1 Work Package 2 Objectives

WP2 produces and adapts 12 Kompaï platforms to the MARIO user, functional and technical requirements for their use in the project R&D and validation work packages. It implements the platform hardware, sensor and communication modifications so that the platform can support the development of the STOs and input from WP1. WP2 objectives are therefore:

- To make available (as early as possible in the work program) 12 Kompaï platforms adapted for MARIO functionalities and requirements.
- To make the hardware, sensor and communication modifications necessary for MARIO
- To configure the database and establish protocols to ensures the compatibility, communications, ontology between functionalities and implementation of the system architecture
- To configure the intelligent interface 4 Connect + web-based interface that will allow software developers to conduct development and upload their robotic applications and the robot GUI (voice, touchscreen, manual controls and web based reporting).

This deliverable is related to the Task 2.1 - Production & Hardware, Sensor and Communication Modifications

1.2 Purpose and Target Group of the Deliverable

This deliverable describes the architecture of the system with regards to its:

- Mechanical design
- Mechatronic architecture and choice of main components,
- Control system hardware architecture
- Software architecture

This document is the main input to the production process of the robot and targeting mainly software developers and robotics expert.

1.3 Relations to other Activities in the Project

This deliverable uses as inputs: WP1- D1.1 : Mario System requirements

This deliverable is an input to: WP4, WP5, WP6 and WP7

1.4 Document Outline

This deliverable is organised in 5 Sections, where the first one gives an introduction to this deliverable in the context of the MARIO project, whereas the second section presents the main requirements and Background from previous founded projects. Sections 3 and 4 present detailed information about the hardware and software architecture of the robot. Robots attribution and Conclusions are provided in Sections 5 and 6 respectively.

1.5 About MARIO

MARIO addresses the difficult challenges of loneliness, isolation and dementia in older persons through innovative and multi-faceted inventions delivered by service robots. The effects of these conditions are severe and life-limiting. They burden individuals and societal support systems. Human intervention is costly but the severity can be prevented and/or mitigated by simple changes in self-perception and brain stimulation mediated by robots.
From this unique combination, clear advances are made in the use of semantic data analytics, personal interaction, and unique applications tailored to better connect older persons to their care providers, community, own social circle and also to their personal interests. Each objective is developed with a focus on loneliness, isolation and dementia. The impact centres on deep progress toward EU scientific and market leadership in service robots and a user driven solution for this major societal challenge. The competitive advantage is the ability to treat tough challenges appropriately. In addition, a clear path has been developed on how to bring MARIO solutions to the end users through market deployment.

2. Main project requirements

This section describes the system requirements and their origins.

2.1 Requirements from MARIO project user study

From the list of requirements identified in the task 1.2 we have selected the following requirements that have an impact on the specifications of the robot:

- The system must be able to move within the operating environment.
- The system must be able to perceive its operating environment.
- The system must be able to perceive the user.
- The system must show cognitive ability in its operation.
- The system must execute a range of different applications
- The system must have the ability to be configured.
- The system must provide connectivity internally and externally from the operating environment.
- The system must be able to interact with the user.
- The system will be able to make autonomous decisions.
- The system must show social ability in its operation
- The system should provide a detachable device to communicate with the user.
- The system should be able to detect specific objects within its operating environment.
- The system should be sensitive to ethical concerns in its storage and use of data
- The system must be able to perform time and calendar based functions
- The system must be able to perform functions based on location.
- The system must be able to perform functions relating to people.
- The system must be able to carry out communication based functions.
- The system must be able to guide the user through a sequence of actions step by step.
- The system must be able to log usage.
- The system must have an understanding of spoken language.
- The system must be able to recognise the user
- The system must provide flexibility in the flow of user interactions.
- The system must be composed of mechanical components appropriate to the application.
- The system must be able to present information to the user.
- The system must be able to accept input from the user.
- The system must be able to communicate with devices in the environment.
- The system must be able to sense the environment.
- The system must be able to sense the user.
- The system must be able to communicate within the operating environment.
- The system must be able to communicate externally to the operating environment.
- The system must be able to execute applications.
- The system must provide a detachable device the user can use when away from the platform
- The system should be able to operate while charging.

- The system touch screen must be adjustable.
- The System must comply with regulations necessary for the legal operation.
- The system should comply with prevailing standards relevant to its operation.
- The system must keep a log of failures.
- The system must fail safe.
- The system must have a remote control capability so that it can be controlled moved remotely.
- The system must be able to accept push updates.

2.2 Additional Requirements

The robot must include several additional functions:

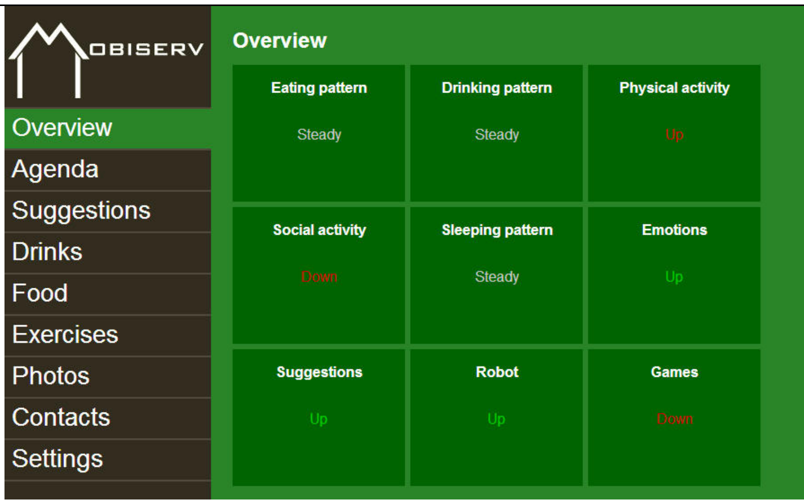
- SOS button
- Self-recharge at the docking station
- Able to follow the user
- Able to receive user computer and user applications communicating with robot services through web interface
- Able to receive JIBO head instead of the standard one

2.3 Background results from past founded projects

Background from past founded projects is illustrated in the following table

Project	Background
DOMEO	Thanks to DOMEO project, the first version of the Kompaï R&D robot was born in 2010. This Kompaï R&D is an indoor mobile platform with two propulsive wheels used as a generic platform and designed to ease the development of advanced robotics solutions. It can recognize and synthesize a voice, and navigate in unknown environments. It also remembers meetings, manages your shopping lists, plays music and can be used as a video conference system. It is equipped with an embedded controller running Windows CE for low level control, and with a tablet-PC running Windows Embedded Standard 7 for high level applications. In this project it was used as a personal assistant for elderly persons, as tele-presence device and rised doubts.

	 Kompaï R&D Main specification : **Dimensions** : L x l x h = 455 x 41 x 125 mm **Ground clearance:** 50 mm **Weight:** 31Kg **Number of wheel:** 2 propulsive wheels, 2 castor wheels **Direction:** Differential type **Max speed:** 1 m/s **Batteries:** Li-ion 24 VDC – 20 Ah **Embedded controller:** Pure for low level and robuBOX-Kompaï for high level **Operating system:** Windows CE 6.0 for embedded computer and Windows Embedded Standard 7 for tablet PC **Driving mode:** Xbox 360 wireless gamepad, automatic navigation
MOBISERV	Thanks to MOBISERV we could enrich the functions performed by Kompaï such as: 1- Ability to make the robot say arbitrary sentences. - Ability to make the robot ask user to repeat. - Navigation to points of interests. - Rotate 25° left or right, and 180° rotation. - Trigger suggestions. 2- Encouragement to eat / drink 3- Adding physical exercises and Encouragement to exercise 4- Adding games 5- Photo album 6- Emotion recognition and suggestions

	 MOBISERV GUI Interface
iTalk	The theoretical and methodological progresses achieved within the Integration and Transfer of Action and Language Knowledge in Robots (ITALK) projects provided an important background for designing the software architecture of the Mario robot with particular reference to the relation between the knowledge base and the action and behavioral capabilities of the robot. Moreover, experience gained within the ITALK project provided important guidelines for the design of the software component that is in charge of behavior arbitration. The specific software components that were developed within the ITALK project could not be exploited due to the fact that the project was based on a completely different robotic platform and addressed the acquisition rather than simply the usage and the adaptation of language and action skills.
HOPE	Thanks to HOPE Project, a Smart Home automation was implemented to maintain the independence and safety of elderly people with dementia. The Smart Home allows the elderly to stay in their homes where they feel comfortable, instead of moving to a health care facility. The transition to a health care facility can cause a lot of anxiety and home automation can either prevent or delay this anxiety. Smart homes can provide the elderly with many different types of emergency assistance systems, security features, automated timers, and alerts. These systems allow for the individual to feel secure in their homes knowing that help is only minutes away. Smart home systems will make it possible for family members to monitor their loved ones from anywhere with an internet connection. In the HOPE Project, it was demonstrated that the use of a domotic system can improve the functional, nutritional, cognitive, affective and neuropsychiatric state. Furthermore, the domotic system can improve the customer’s satisfaction and quality of life [1].

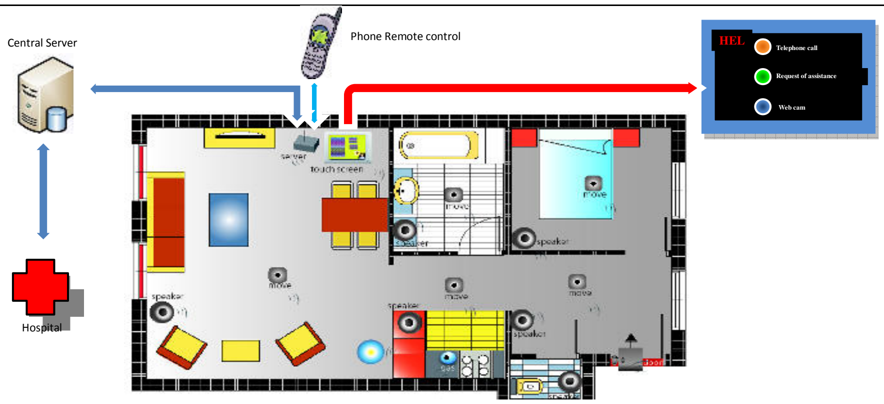
	 [1] Pilotto A, D'Onofrio G, Benelli E, Zanesco A, Cabello A, Margelí MC, Wanche-Politis S, Seferis K, Sancarlo D, Kilias D. Information and communication technology systems to improve quality of life and safety of Alzheimer's disease patients: a multicenter international survey. J Alzheimers Dis. 2011;23(1):131-41.

Table 1: Background results from past founded projects

2.4 Kompaï R&D VS MARIO-Kompaï2 futures

The following table summarises the difference between the first version and the customized one for MARIO project:

Item	**Kompai 1**	**Kompai 2**
Obstacle detection	Only one horizotal front laser used for navigation and obstacles avoidance	One horizontal in the front for navigation and front obstacles avoidance, one in the back and one vertical in front for obstacles detection
3D sensor	Fixed kinect 1	Kinect 2 with motorized tilt +-20°
Torso	Fixed	Motorized
Computing	One tablet PC running navigation and robot application	2 power full computer one running Windows OS for navigation and standard functions provided with Kompai robot. The second running any other OS for additional functions developed by partners.
Head	Fixed head	Animated head and removable for the possibility to replace it by Jibo head (MARIO project requirement)
Autonomy	Depending on the scenario it is about 3h	Double
Quality of sound	Normal	Additional amplifier to adjust the quality of sound
High level software interface	Under MRDS based programming environment	Web based programming technology

Table 2: Kompaï1 VS Kompaï2 futures

3. Hardware architecture

3.1 Specifications of the MARIO Kompaï

This project must consider many specifications described in the following table

Feature	Specification
Kompaï weight	< 50 kg
Motorization	Electric
Propulsion	2 Wheeled
Steering	Differential control of wheels speed
Dimensions	Height x Width x Length = 1330 x 460 x 460 mm
Obstacle clearance (vertical step)	> 1 cm
Max slope	< 10%
Energetic autonomy	> 5h
Sensors	
User visual detection	Microsoft Kinect 2
Navigation and anti-collision	2 lower laser scanners for navigation and anti-collision, 1 vertical laser scanner for anti-collision only.
Floor detector	2 frontward and 2 backward
On-board computing & functions	
Robot's PC	Advantech industrial PC with Windows 8.1
User's PC	Gigabyte mini PC with windows 8.1
Screen interface	Main Touch Screen + Mini eyes screen
Communication	
Wifi, 3G, 4G	All-inclusive module

Table 3 : Main specifications of the MARIO Kompaï

3.2 Hardware description of the Kompaï-MARIO robot

As illustrated in Figure 1, the mechanical architecture of the Kompaï-MARIO is based on:

- 4 wheels platform with 2 driving wheels in the centre and 2 free wheels in the front and back.
- Steering by differential speed, each wheel being independently controlled.

The navigation will be made with two lasers which cover the 360° around the robot. The same lasers will also be used for the anti-collision function. To be able to detect high objects like tables, we also have a vertical one.
The torso will be able to move with an angle of ±180°. The motorisation of this mobility will allow the Kinect to track the user. It also can be orientated manually by means of a switch.
The Kinect will rotate up and down by motorisation (0°; -15°). It permits the robot to follow the head of the user or to detect someone on the floor. The touch screen will be orientated manually by the user by means of friction hinges.

3.3 Mechanical and energy architecture

In this sub-section we detail the mechanical design of the robot and its energy resource.

3.3.1 Mechanical design

The mechanical architecture of the robot is the one proposed in the following figure and is mainly based on:

- 4 wheeled platform with 2 central drive wheels, one front free wheel and one rear free wheel.
- Steering by differential speed
- Each motorized wheel is independently speed controlled.

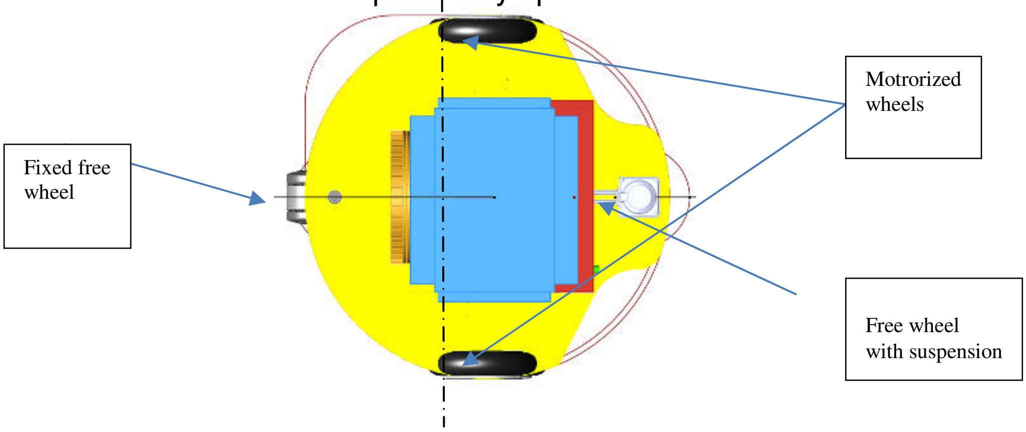


Figure 1: Mechanical design of the robot

3.3.2 Traction motor dimensioning and choice

By combining the conceptual architecture and mechanical clearance requirements, a series of calculations were performed to determine needed step-clearance torque for the traction motors. Parameters such as total weight are estimated for these initial calculations. Iteration will be done once these parameters are better known.

The following table summarizes the results of this calculation taking in the account the weight of the first prototype

Total estimated weight	50	Kg
Maximum velocity	7,07	Km/h
Acceleration time	1,2	s
Nominal motor velocity	2500	Tr/min

Reduction gear	10,00

Acceleration mode with 3% normal slope

	Total power	Power/wheel	Torque	Torque/wheel	Torque/motor
Aerodynamic effects	1	0	0,03	0,02	0,00
Friction effects	19	10	0,74	0,37	0,04
General slope effects	29	14	1,10	0,55	0,06
Acceleration effects	149	74	5,66	2,83	0,28
total	197	99	7,53	**3,77**	**0,39**
	w	w	Nm	Nm	Nm

Step clearance 20mm

Total force to climb	20	DaN

	Torque	Torque/wheel	Torque/motor
Static mode	15	7	0,76
	Nm	Nm	Nm

Table 4: *Calculation of the traction motors power on flat surface and for step clearance*

3.3.3 The Traction gearmotor and power controller

The motogear:	**AE050 + BL053 Motor from Infranor**
Nominal output speed	250rpm
Nominal output torque	4Nm
Acceleration torque	12Nm
Total length	183mm (Gear 63mm + motor 120mm)
Axial load	350N
Radial load	702N
Noise	< 56dB at 3000rpm input speed
The BL053 Motor:	**BL53(24V) Motor + encoder +Hall sensors**
Nominal torque	0,4Nm at 2500tr/mn
Nominal current	8,16A
Maximum torque	1,6Nm,
Maximum current	32A
Torque constant	0,05Nm/A
Brake	24Vdc
Protection	P54
The Gear AE050	**Planetary gear series AE, type 050**
Backlash	< 8"
Reduction ratio	1/10
Nominal torque	14Nm
The motor drive:	**DZCANTE 40/80 from Advanced Motion Control**

Nominal current	20A
Maximum current	40A
Interface	CANopen

Table 5: Traction system specification

3.3.4 Torso rotation motor dimensioning

As illustrated in the following figure the torso rotation use an external tooth crown.

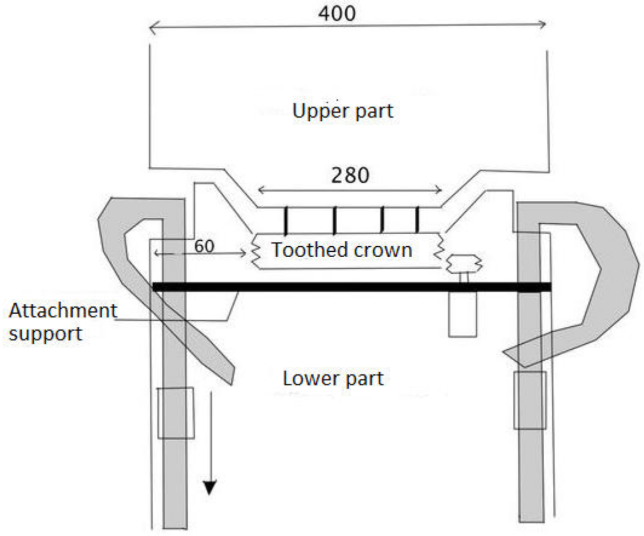


Figure 2: The torso rotation principle

To identify the needed motor power we are using the following data:

- Total weight of the upper part: 15Kg
- The diameter of the tooth crown : 40cm
- The gravity center is on the rotation axle

The following table gives the motor power calculation.

r	0,02	m
Initial speed	0	°/s
Final speed	20	°/s
Acceleration time	1,2	s
Acceleration	16,667	°/s2
Inertial moment of the crown	0,003	Kgm2
Ca: Acceleration torque	0,872	mNm
Crv: Transmission torque	2,500	Nm
Crc: ball bearing	0,090	Nm
Cg: Gyration torque	2,591	Nm

Table 6: Torso motor specification

The integrated set of motor and gear answering this power are from Faulhaber :

- Motor ref: EN_3268_BX4_CX_DFF

- Gear ref: EN_32ALN_DFF ; r=14

Considering a ratio of 6 between large and small motor pinion gear the total torque developed by this set is up to: 6,8Nm

3.3.5 Kinect tilt motor dimensioning

As illustrated in the following figure the Kinect tilt is motorized assuming 0 to 15° tilting.

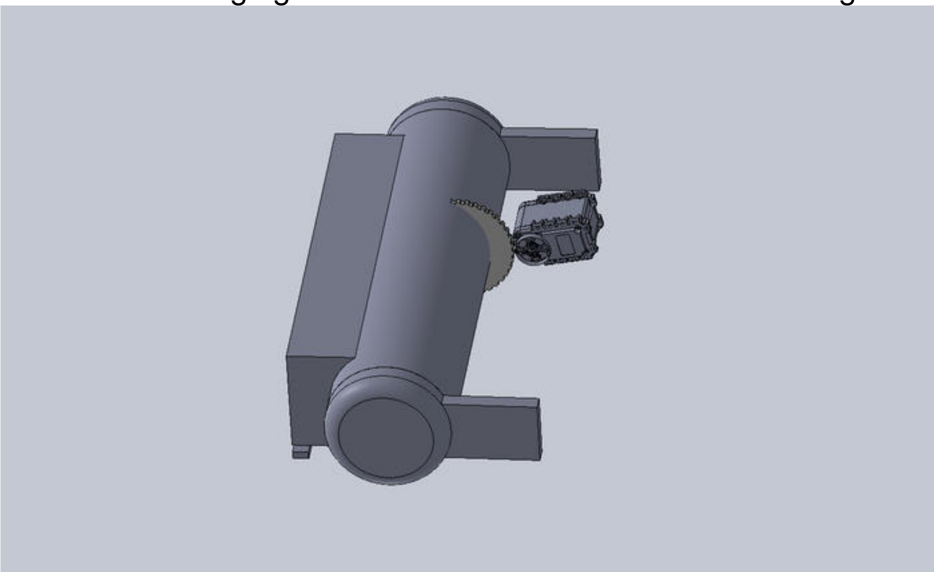


Figure 3: Kinect tilting motorisation

Assuming that no balancing weight is used, the motorisation can be achieved using a single servo motor from Hitec (HS-8380TH High Voltage, Ultra Responsive, Ultra Torque Titanium Gear Servo).

3.3.6 Synthesis of mechanical components

Article	Designation	Photo	Ref.	Brand	Supplier	Qty
	Propulsion wheel		RNP 150/30-D8 LM36 5 Rayons		Tente SAS	2
	Free wheel		5920UJI075L51-10		Tente SAS	2
420015	Traction motor		BT053	Infranor	Infranor	2
	Gear		AE050	Infranor	Infranor	2
	Breake		ROLIVAM Brakes		Infranor	2

Article	Designation	Photo	Ref.	Brand	Supplier	Qty
	Encoder		RMC22	RLS	Infranor	2
425007	Power controller		DZCANTE-040L080	AMC	AMC	2
	Rotation torso motor		EN_3268_BX4_CX_DFF	Faulhaber	Faulhaber	1
	Rotation torso gear		EN_32ALN_DFF; r=46:1	Faulhaber	Faulhaber	1
	Kinect tilting motor		HS-8380TH	Hitec		1

Table 7 : Mechanicals components

3.3.7 CAD Volume

In this sub-section we will introduce some view from the CAD system to illustrate the embedded equipment and what the robot looks like.

3.3.7.1 Overall size and external labelling

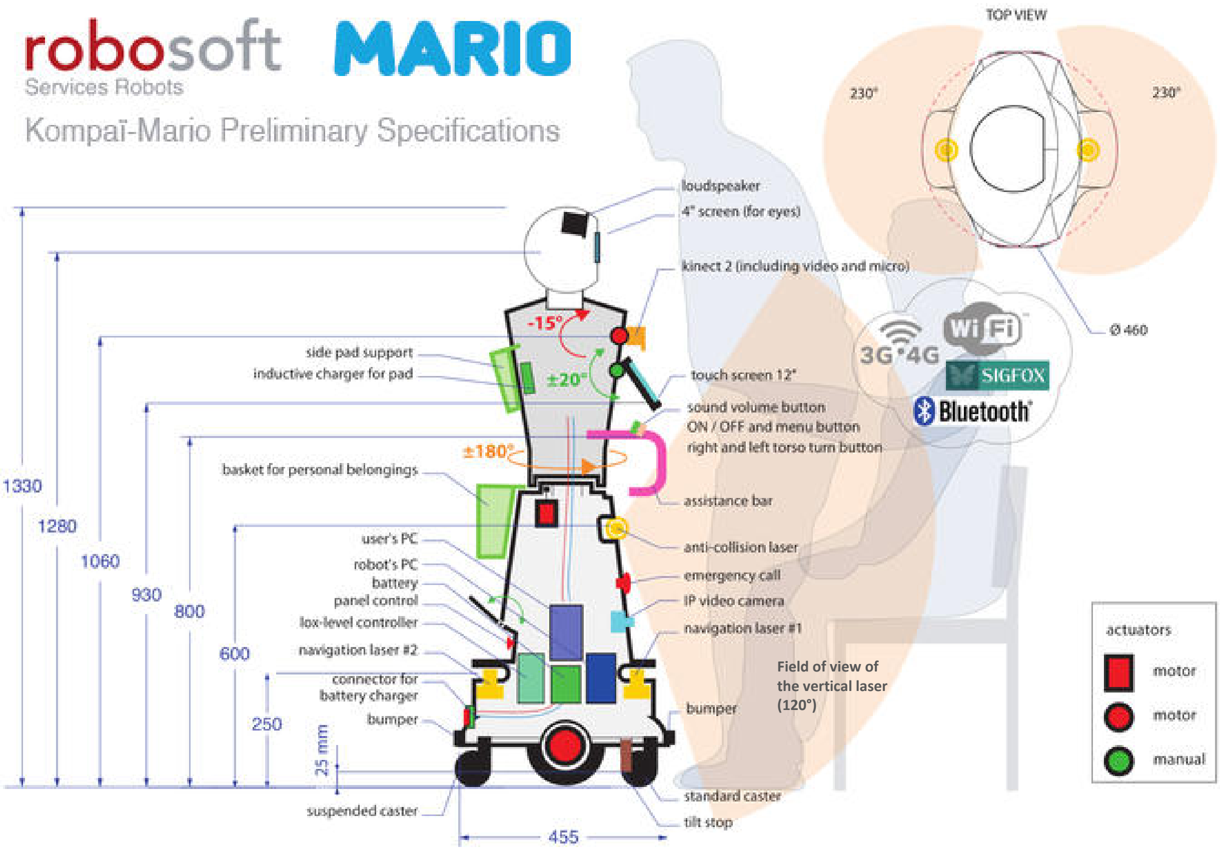


Figure 4: Robot architecture

3.3.7.2 Set of conceptual design views

The following views gives an idea on what the Kompaï robot looks like, its size with compare to normal person and its accessibility when setting on a chair. Exploded views are presented in the annex 1 as a result of this design.

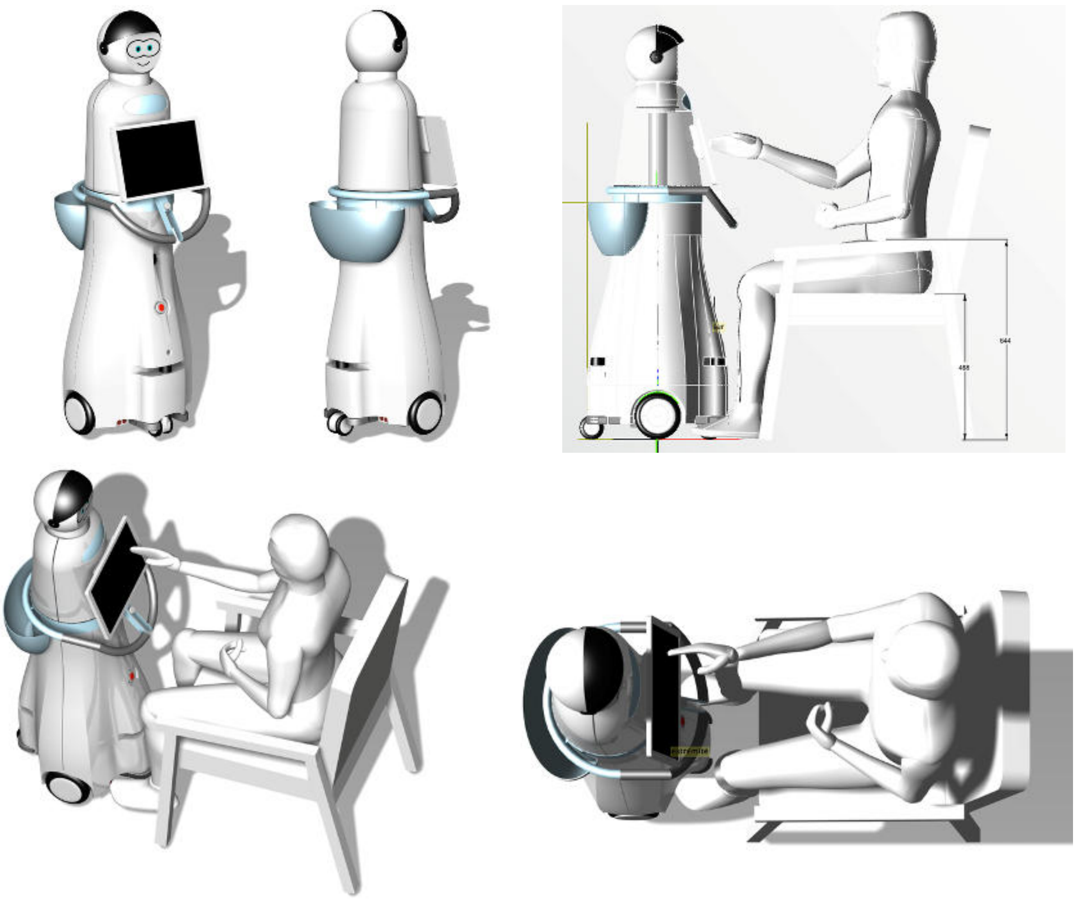


Figure 5: Conceptual views

3.3.8 Energy System design

3.3.8.1 Conceptual Architecture of the energy and electrical systems

The architecture below is based on the experience of Robosoft in building battery-powered vehicles.

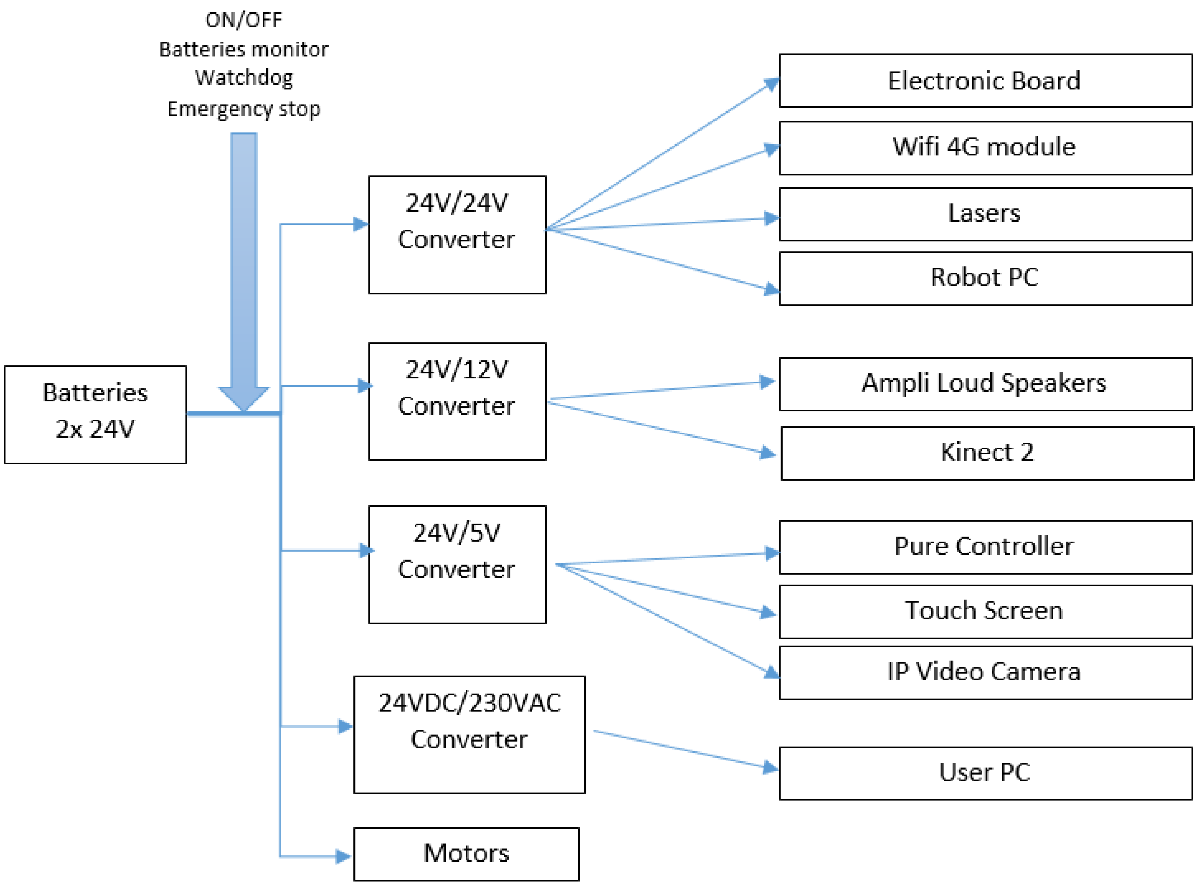


Figure 6: Energy system architecture

3.3.8.2 Battery dimensioning based on usage scenario

The battery size is defined in accordance with a typical usage scenario. The robot must have at least 5 hours of autonomy. During this time, we assume that the user will approximatively spend 1 hour on the internet, 1 hour listening music, 30 minutes playing a game and 30 minutes on skype. The robot will move 10 times with an average distance of 15m (5 times voice called, 2 times following the user and 3 times for user safety checking).

As illustrated in the annex 2 table, the battery size is based on the power consumed by the traction motors and all the components on board during this scenario. From this calculation we are assuming at least two batteries of 20,8Ah under 24V.

3.3.8.3List of energy system components

Article	Designation	Photo	Ref.	Brand	Supplier	Qty	Anx.
430005	Battery Li-ion		7S/8P 26V 20,8Ah BMS 25A 18650		Leclanché SA	2	ATF11

Article	Designation	Photo	Ref.	Brand	Supplier	Qty	Anx.
439005	Ctrl_Batt_ BMV700_9-95Vdc		BAM010700000	Victron	Victron	1	ATF12
432002	Batteries charger		Charg_LiIon_7Cell_230Vac_29p4Vdc_10A		Leclanché SA	1	ATF13

Table 8: Energy components

3.3.8.4 Docking station

The robot is provided with its docking station to charge batteries as shown in Figure 7. This device must be connected to the 220V supply. Once the position of the docking station is mapped during initial system setup, the robot can reach the docking station automatically when its battery level is low.

Figure 7 : Docking station

3.3.9 Estimation of the total weight of the platform

Table 9 in the following section gives the weight of each component. A first approximation gives a total weight of about 50 kg. The approximate position of centre of gravity is calculated in the annex 3 table.

3.4 Control system hardware architecture

The architecture of control system specifies the elements needed to drive the platform, the man-machine interfaces, etc. This section describes the hardware aspects only. The software aspects are defined in Section 4, Software Architecture.

3.4.1 Architecture scheme

The architecture of the system is based on 3 levels (figure 8):

- PURE low level control board connecting main devices of the mobile base such as traction motors, torso and Kinect motors, sensors used for navigation and obstacles avoidance, IP camera, floor sensors and BMS through CAN bus, Ethernet or serial line. This type of connection makes possible the addition of future sensors or actuators.
- Robot's PC connecting the devices related to the application such as the Kinect, the HMI, the speakers,
- The User's PC for additional devices and functions not covered by the robot's PC

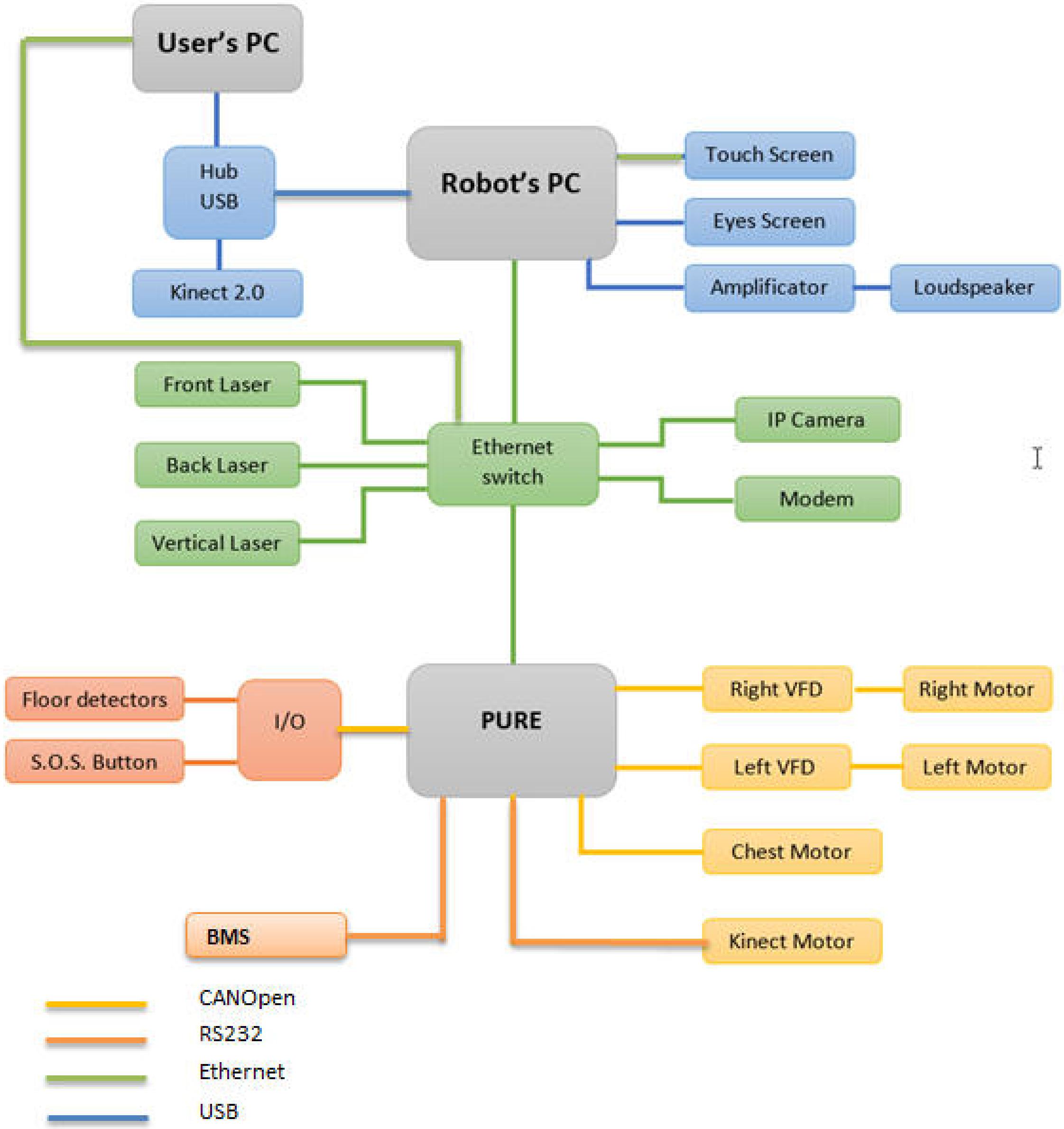
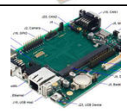


Figure 8: Control architecture

3.4.2 List of control system components

Article	Designation	Photo	Ref.	Brand	Supplier	Qty	Anx.
[450009]	Robot PC		UNO 2184G D64E	Advantech	Integral System	1	ATF14
[450004]	PURE control board		Carte_CE_EMTRION_DIMM-Eco-Base_CADUN	Emtrion	Emtrion	1	ATF15
[450003]	PURE mother board		Carte_CE_EMTRION_DIMM-MX537-3-512MBRAM-512MBFlash	Emtrion	Emtrion	1	ATF16

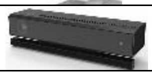
Article	Designation	Photo	Ref.	Brand	Supplier	Qty	Anx.
[446007]	Touch screen		Lenovo ThinkVision LT1423p	Lenovo	Adour Bureau	1	ATF17
[446008]	Eyes screen		DPP-T43	Demmel	Demmel	1	ATF18
	USB Hub					1	ATF19
[452003]	Ethernet switch		852-112 (100 Base TX)	Wago	Wago	1	ATF20
[416004]	Ip camera		M1004-W	AXIS	…	1	ATF21
[416021]	Kinect 2		Kinect 2	Microsoft	Microsoft	1	ATF22
	Modem					1	ATF23
[410010]	Navigation laser		Tim561	Sick	Sick	2	ATF24
[410010]	Vertical laser		Tim561	Sick	Sick	1	ATF24
	Floor detector		GTB6-P4211	Sick	Sick	4	ATF25
[440026]	SOS button		513-3593	EAO	RS	1	ATF26
[443009]	Loudspeaker		Visaton PL5	Visaton	RS	2	ATF27
[443004]	Amplifier		CA9.2	CIE	RS	1	ATF28

Table 9: Control system components

4. Software architecture

There are three layers of software for different uses:

- **PURE**: low level control software. It is designed to perform tasks such as actuator control, sensor data acquisition, feedback control and robot supervision.
  It is possible to communicate with PURE through a UDP or TCP protocol.

- **robuBOX**: middleware that bring high level functionalities to Robosoft's robots such as
  - Interface with PURE,
  - GUI,
  - Navigation,
  - Etc…

  It is possible to communicate with robuBOX through http/JSON protocol.

- **HMI**: a multimodal Human Machine Interface that propose various interactions for users.

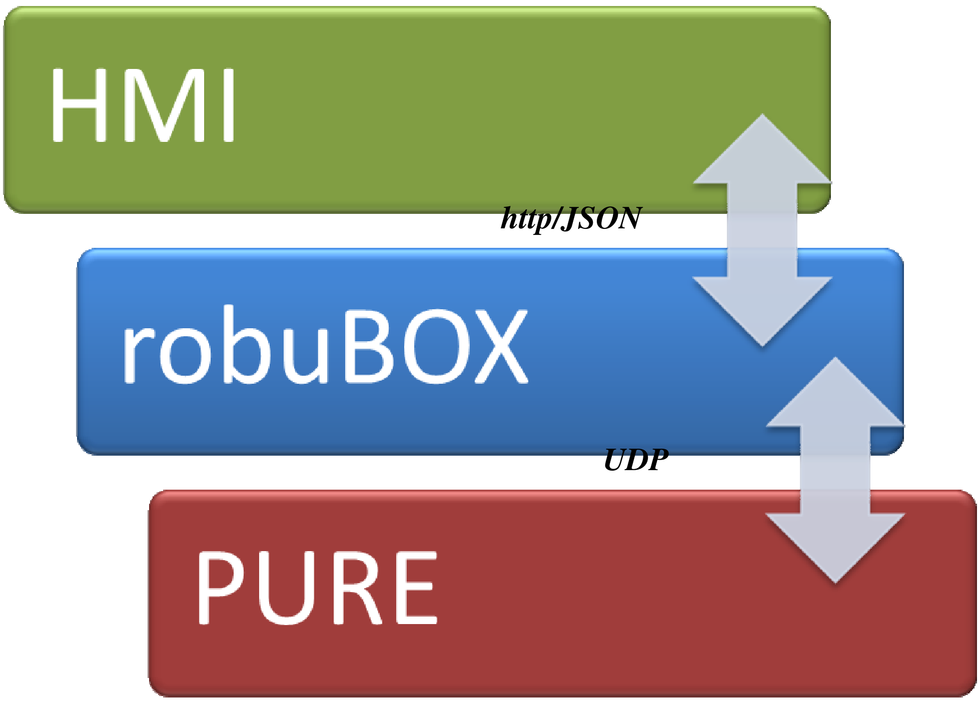


Figure 9: Main software architecture

4.1 PURE

PURE interfaces hardware and software; it is running under windows CE on an Emtrion board and is real-time.

It is possible to communicate with PURE through its UDP protocol described in the PURE documentation: pure-communication-manual-4.1.pdf.
Its main functionalities are:

- Sensor feedback and actuator control
- Kalman filter on localization
- Feedback control

4.1.1 Kalman filter on localization

The PURE localization module output is derived from a Kalman filter that mixes odometry information's and corrections. Those corrections can be provided by SLAM navigation module or GPS for outdoor navigation.

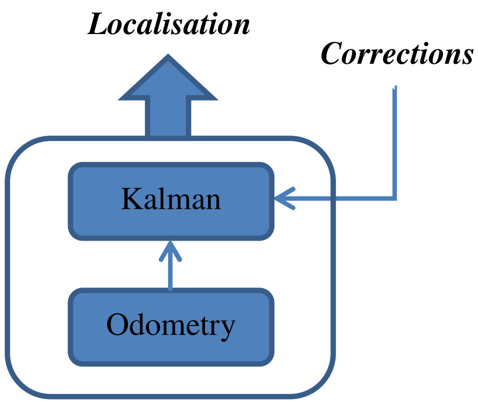


Figure 10: Localization module architecture

4.1.2 Feedback control

PURE allows execution of a trajectory, with respect to the localization described previously. The output is limited by an anti-collision algorithm which will stop the robot if an obstacle is detected by the laser.

It also allows "steps" to move the platform. Upon reception of a new command, PURE will compute a motion profile based on the maximum speed specified. The profile will be trapezoidal, or triangular if the required displacement is too small to accelerate to the specified maximum speed.

4.2 robuBOX

The robuBOX is an open source Software Development Kit (SDK) developed by Robosoft, and based on Microsoft Robotics Developer Studio (MRDS) and developed in C#.It is running on a regular computer equipped with windows 7.

robuBOX can provide various different configurations in order to fill the user's need. For Kompaï base three configurations are mainly used:

- The mapper configuration that allows the generation of a map of the environment,
- The localizer configurations that localize a robot inside a map generated with the mapper.

- The navigation configuration that add automatic motion capabilities to the robot.

4.2.1 Mapper

The mapper configuration is used to generate a map of the environment using laser and odometry data as input.
The following schema exposes relations between services that constitutes the configuration. Services used for GUI are not displayed.

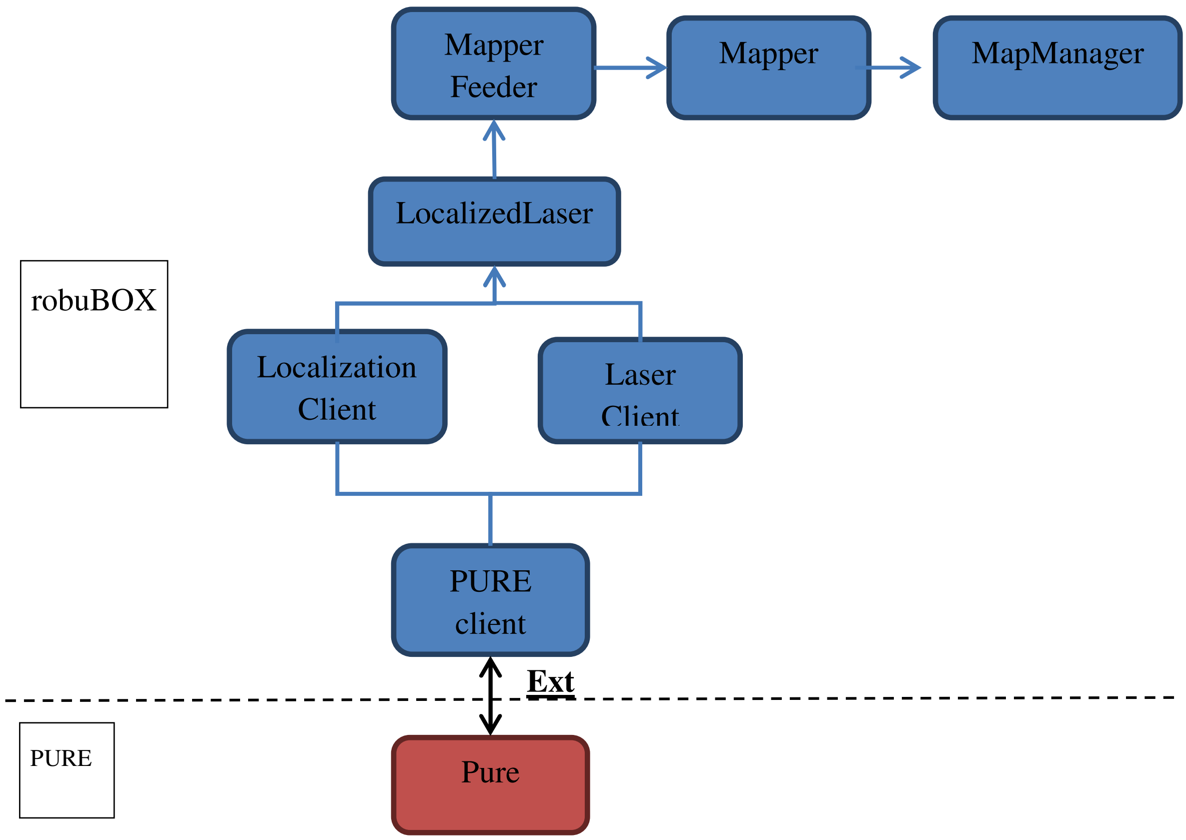


Figure 11: Mapper architecture

RobuBOX connects to PURE using the ***PUREClient*** service. This service dispatches data to the ***LocalizationClient*** and ***LaserClient*** that interfaces the Localization and the Laser from PURE.
LocalizedLaser synchronize laser data and current localization.
MapperFeeder gets ***LocalizedLaser*** data and feeds the ***Mapper*** that generates a map. This is done so that it is possible to feed the mapper with different localized laser data at the same time. The map is stored inside the ***MapManager*** service.

4.2.2 Localizer

The localizer configuration computes the robot's localization inside a map. This localization is sent as correction to the Kalman filter of the localization of PURE.

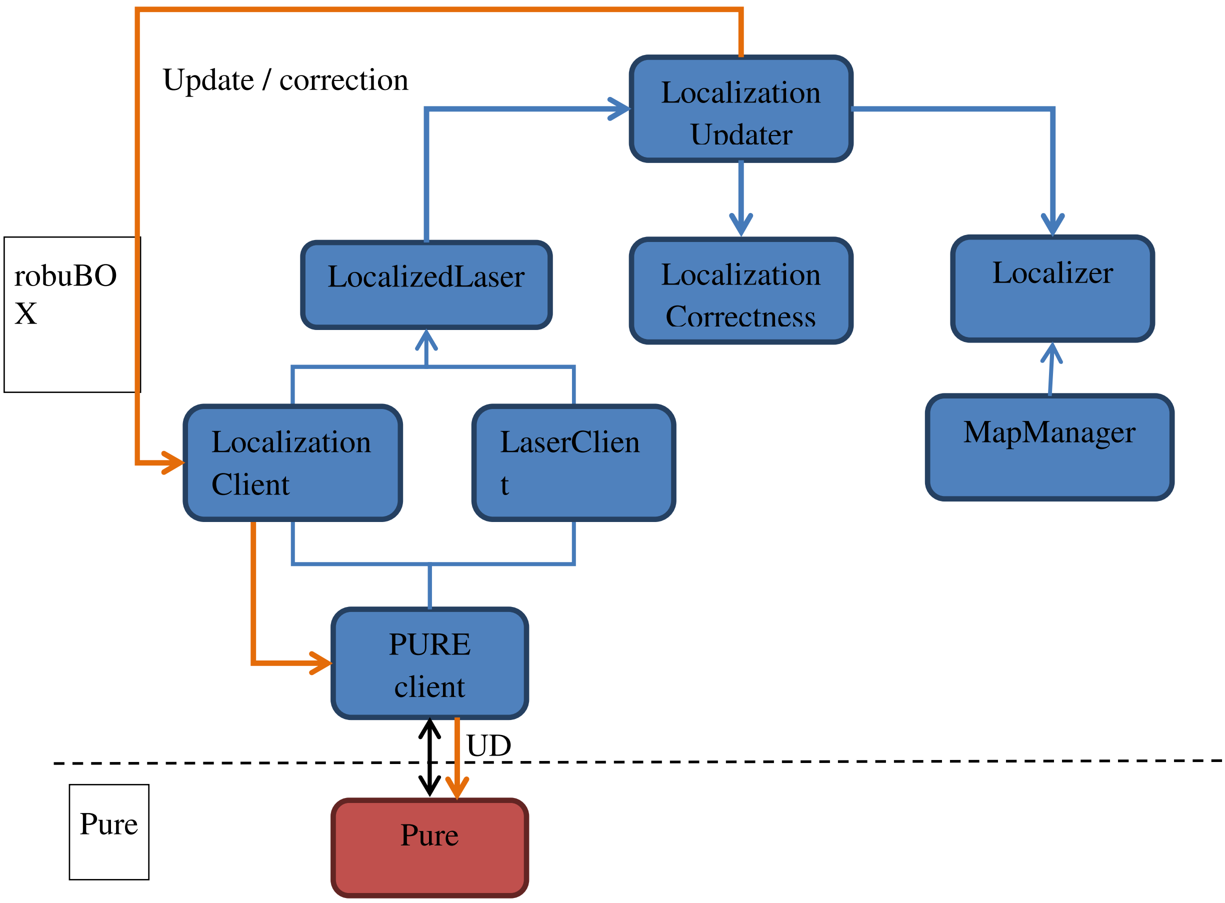


Figure 12: Localizer architecture

RobuBOX connects to PURE using the ***PUREClient*** service. This service dispatches data to the ***LocalizationClient*** and ***LaserClient*** that expose interfaces.
LocalizedLaser synchronize laser data and current localization.
LocalizationUpdater grabs localized laser data and request to the ***localizer*** to compute a localization of the robot inside the map. Once it gets a response it checks the validity of the data using ***LocalizationCorrectness***.
If the response is valid the correction is sent to the Kalman filter in PURE through ***LocalizationClient*** interface.

4.2.3 Navigation

This configuration is coupled with the localizer configuration. Its purpose is to automatically generate a trajectory through a map using the robot's localization and the destination to reach as inputs and make the robot follow it.

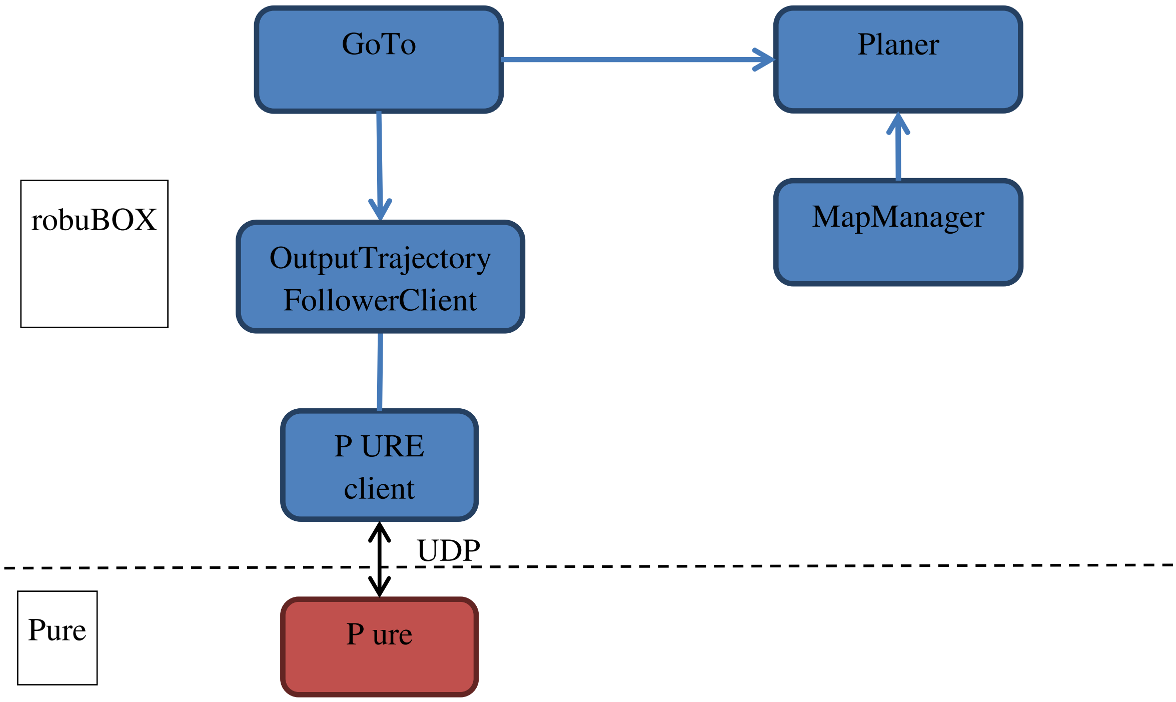


Figure 13: Navigation architecture

GoTo service receives a displacement request from a user. The service requests to the planner to generate a path through the map.
When the path is generated it is transformed in trajectory and sent to the trajectory follower algorithm from PURE.
It is possible to communicate and control the navigation configuration using **Http/JSON interfaces**.

4.3 HMI

The human machine interface is a program that will be used by the end user. It can be controlled through voice or touch and offers several functionalities such as event reminder, videoconferencing and access to the weather. It is developed in C# and requires some software installation before it can be used. This HMI will interact with the GUI interface developed under Task 2.3.

4.3.1 GUI interface developed under Task 2.3

This is the User interface that has been carried out using the following steps:

a) Using the descriptions in D 3.4 the phasing of App delivery has been set for each trial.

b) User interaction proposed for each App has be assessed to ensure the cognitive load is appropriate for PwD.

c) A trial set of screen sequences has been developed for each App and distributed as Web Pages so that an interactive test of the look and feel of the interface can be made by the pilot sites.

d) Assessment of feedback from the pilot has been used to inform design changes.

The first round of App development has concentrated on the delivery of the following Apps:

- Music
- News
- Games

A second round of App development will concentrate on:

- CGA
- Activities

Both rounds of development will deliver Apps for Phase 1 Trial 1.

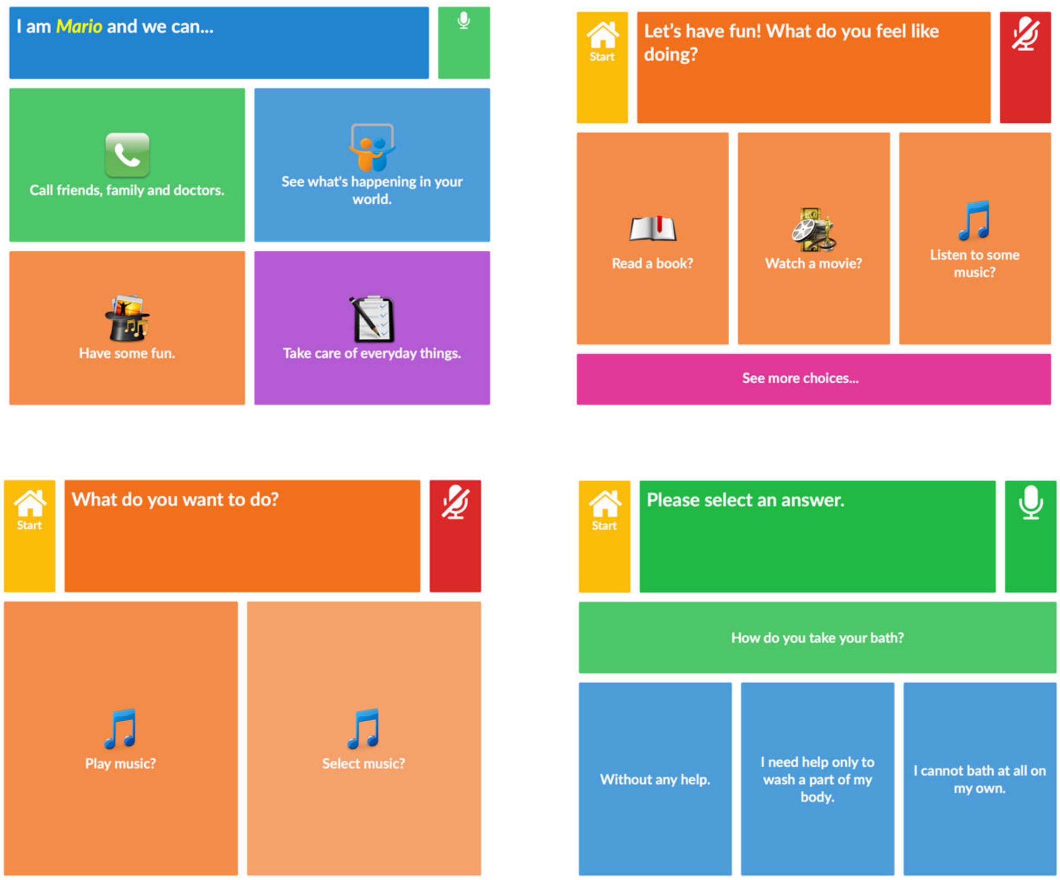


Figure 14: User interface screen examples.

The user interface screen flow can be examined at the following web site:

http://www.mario-project.eu/dev/uidesign/index.html

Figure 14 provides four samples of the graphical layouts of for the User Interface. The bottom right-hand image is one of the CGA questions and is typical of the response screens used on MARIO. There is a degree of customisation that can be carried out with respect to font size and colours. Each screen is accompanied with spoken output.

The UI is based on web pages and a browser is used as the main interface medium. This allows easy simulation of the user interface both over the internet and on a laptop. This has been used to trial the user interface design at the pilot sites and between developers.

Care has been taken to make the cognitive load of each screen and the sequence of screens suitable for a PwD. However careful assessment based on observation of interactions will be used to provide an ongoing assessment of suitability

4.4 Data management (Task 2.2)

Within Task 2.2 we identified all the data that will be stored and managed in the ontology database developed within the Task 5.1. The following table illustrates all these data, who generating, who using and who managing each of them:

Data group	Required data to store and manage	Who generates this data	Who will use it	Concerned by ethical (Y/N)	Who responsible to manage this data	The way to manage it
Robot log files	Map	Robot API (Robo)		N	Robo	
	Lasers scan	Robot API (Robo)	Behaviour module (CNR)	N		
	Other data required for debug	Robot API (Robo)	Robo	N	Robo	Through CNR API
Voice	Raw data	Kinect API (Robo)	S2T module	Y	CNR	
	Text from S2T	API (Robo), Dialogue	CNR	Y	CNR	
	T2S	Dialogue	CNET		CNR	
Video	Image from Kinect camera	Kinect API (Robo)	Face extraction (ORTELIO)	Y	ROBO	
	Skeleton	Kinect API (Robo)	CNR (behaviour module)	N	ROBO	
Calendar & events	events, appointments	web UI (remote or local)	Ortelio - App	N	Ortelio	CalDAV
	Medications reminder	web UI (remote or local)	Ortelio - App	N	Ortelio	CalDAV
Personal data	Vital signs data	Fitbit, Zephir, Beddit (RUR)	Healthcare Professionals	Y	RUR?	ODBC
User assessment	Mental test data	CGA (CNR)	Healthcare Professionals	Y	CNR?	ODBC
	Physical data (Gait analysis)	CGA (CNR)	Healthcare Professionals	Y	CNR?	ODBC
	MMSE test data	CGA (CNR)	Healthcare Professionals	Y	CNR?	ODBC
Reminiscence	memories, persons, events, questions	Web UI (remote or local)	Ortelio - App	Y	Ortelio	MySQL or Graphs
	Music files	Robo				

Ontology	Persons, their roles, and relationships among persons	Healthcare Professionals through configuration/personalization UI; Acquired as a result of human-robot interactions (e.g., dialogue)	Any App requiring this data	Y	CNR	Knowledge API
	Activities and life-patterns (e.g., eating, drinking, playing, etc.)	"Monitoring" App; Any App		Y	CNR	Knowledge API
	Emotional state	Sentiment analysis module		Y	CNR	Knowledge API
	Music index/metadata (e.g., playlists, tracks, etc.)	Healthcare Professionals through configuration/personalization UI	Play Music/Entertainement App	N	CNR	Knowledge API
	Online accounts	Healthcare Professionals through configuration/personalization UI or through App-specific configuration UI	Any App that requires a to access a 'service' through a user account	Y	CNR	Knowledge API
	Environment and spatial info (e.g., rooms, furniture, etc.)	Healthcare Professionals through configuration/personalization UI; Acquired as a result of human-robot interactions		N	CNR	Knowledge API
	CGA structure and definition (e.g., questions), and CGA-related info (e.g., test executions, results, etc.)	CGA	Healthcare Professionals/reporting	Y	CNR	Knowledge API

	Tagging for life events and multimedia content	Healthcare Professionals through configuration/personalization UI; Acquired as a result of human-robot interactions	Reminiscence	Y	CNR	Knowledge API
Behaviour module, RFID, ...	User's location in space and user's movement in space	Laser, Kinect, RFID sensors	MARIO	N	CNR	
	User's Posture and User's arm/legs movements	Kinect, RFID sensors	MARIO	N	CNR	
Music data (tracks)	Music files	Robo	ORTELIO	N	ROBO	

Table 10: MARIO Data to be managed

4.5 Additional tools for additional functions development by technical partners

The raw data from the Kinect and some other tools provided by the Kinect sensor will be made available to the other technical partners through the web interface to develop functions such as:

- 3D obstacle detection
- Posture detection
- Face recognition
- Voice recognition

5. Availability of the robots and their attribution

As of January 31, 2016 the first two robots were being finished and prepared for shipment to CNR for software development and testing. The other 10 robots were launched into production in early February for delivery of a robot per week from March 18, 2016. The 10 assembled Kompaï platforms will be ready the last week in May 2016 for partner's software integration before their shipment to tests sites in early September 2016. The delay on these 10 robots has no impact on the project since they are scheduled for the evaluation in September 2016

The 12 robots produced for the project was attributed as following:

- One at CNR Rome for software development and testing (behavioural module, person tracking, object localisation)
- One at CNR Catania for software development and testing (Voice recognition, semantic and anthology)
- One at Robosoft for bug fixing, new software testing before deployment, ..
- 9 robots to be integrated with the new software and sent to pilot site for evaluation early September 2016

6. Conclusion

The architecture developed in this deliverable for customization of the robot perfectly meets the needs of MARIO project. We note the progress in the new architecture of Kompaï functionally essentially with the motorization of the chest, very useful feature for monitoring person as well as the addition of the 2nd user PC for adding functions without altering the existing functionality of the robot running on the Windows PC.

Thank you to the new web interface and web programming, the software architecture is fully modular, opening the door to the use of remote applications and the use of internet of things to even more easily extend the functionalities of the Kompaï robot.

Annex 1. : Exploded view of the robot

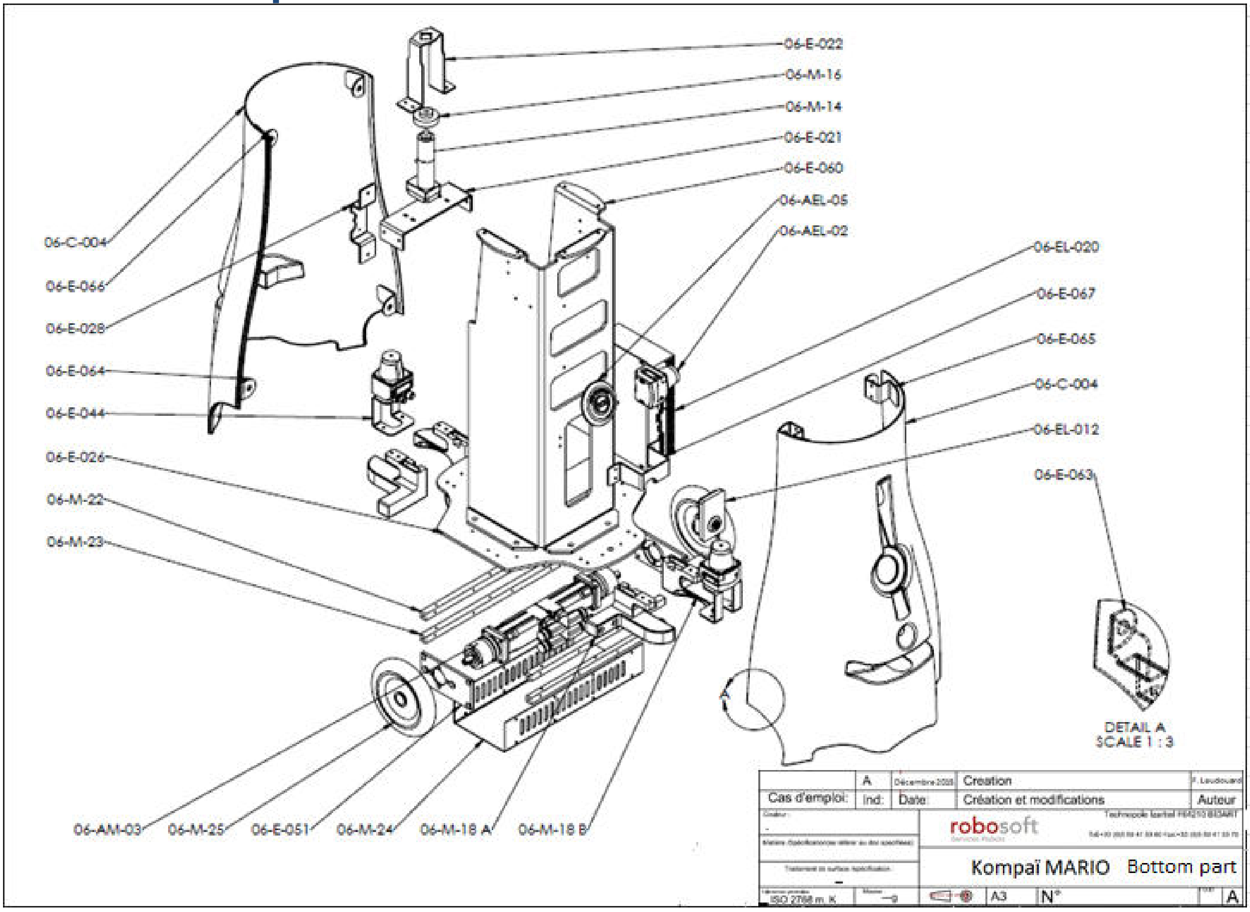


Figure 15: Exploded view of the lower part

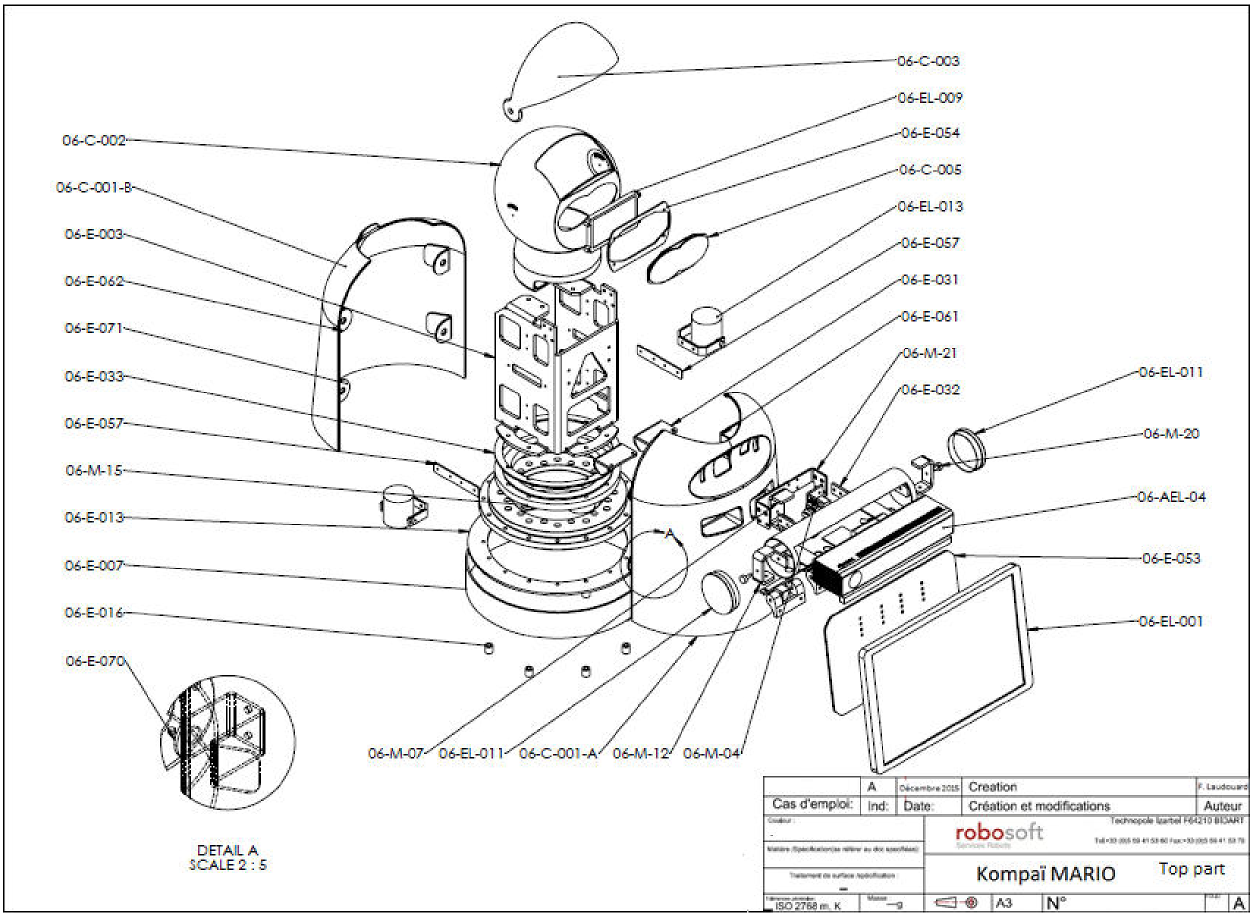


Figure 16: Exploded view of the top part

Annex 2. Consumption calculation

KOMPAI - Scenario of use

Autonomy: 5h

Traction motors consumption

	mn	Km/h	m	W	Ah	Current (A)
Action	Time	Speed	Distance	Power	Consume	
Acceleration	0,04	7,07	2,568	197,034	0,006	8,21
Constant speed	0,10	7,07	11,775	48,903	0,003	2,04
Deceleration	0,04	7,07	2,568	197,034	0,006	
100 times	18,72	0			1,533	0,00
Total time (mn) and distance (Km)	18,72	mn	1691,021	m	1,533	Ah
Total time (h)	0,31	h				

Other devices consumption

Device	Time(h)			Power (W)	Ah	
Robosoft PC in use	3			40	5,000	
Robosoft PC stand by	2			20	1,667	
User PC in use	5			64	13,333	
Pure controller	5			2	0,417	
3x Lasers	15			3	1,875	
Kinect	5			32	6,667	
4x Floor detector	20			0,36	0,300	
Touch screen	5			13	2,708	
Eyes screen	5			1,24	0,258	
Ip camera	0,1			6,5	0,027	
Loud speaker	3			4	0,500	
				Total Ah	34,285	Ah
				Total Wh	822,843	Wh
				Power W	164,569	W

Annex 3. : Approximate position of the center of gravity

	Weight (Kg)	Position (mm)					
Item	P	X	y	z	Px	Py	Pz
Battery 1	2,7	0	0	220	0	0	594
Battery 2	2,7	0	0	310	0	0	837
PURE	1,5	-80	0	250	-120	0	375
Free wheels	0,2	0	0	25	0	0	5
Moto gear + Wheels	5	0	0	80	0	0	400
Chest motor	0,46	-100	100	650	-46	46	299
Chassis					0	0	0
Base slab	2	0	0	117	0	0	234
Bottom frame	1,7	0	0	475	0	0	807,5
Upper frame	1,2	0	0	1000	0	0	1200
Assistance bar	1,5	40	0	800	60	0	1200
Chest bearing	2,2	0	0	800	0	0	1760
PC's					0	0	0
Robot's PC	3	80	0	240	240	0	720
Touch Screen	0,85	130	0	950	110,5	0	807,5
Eyes screen	0,2	65	0	1280	13	0	256
User's PC	1	0	0	450	0	0	450
Speakers (2)	0,2	85	0	1060	17	0	212
Sensors					0	0	0
Front Laser	0,25	150	0	250	37,5	0	62,5
Back laser	0,25	-150	0	250	-37,5	0	62,5
Vertical laser	0,25	115	0	600	28,75	0	150
IP camera	0,1	130	0	380	13	0	38
Kinect	3,2	105	0	1060	336	0	3392
Bodywork					0	0	0
Bottom bodywork	6	0	0	480	0	0	2880
Upper bodywork	3,3	0	0	1050	0	0	3465
Estimated COG position (mm)	39,76	16,40	1,15	508,22	652,25	46	20207