



D7.4 First MARIO system: Achieved functionality _ Final version

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Executive Summary

This report details the outcome of the first MARIO integration task, T7.1. It provides a record of the MARIO system and its available functionality for the Phase 1 Pilot trials. It also provides a baseline statement against which further incremental updates can be made.

This report provides a statement of the delivered status of the MARIO system for the Phase 1 Pilots. It represents not only the culmination of the efforts within T7.1, the first pilot integration task, but also the outputs of the technical work packages WP4, WP5 & WP6 which fed the integration.

The Phase 1 Pilot MARIO systems provided a range of functionality aimed at providing assistance to the user and entertaining the user. These enabled evaluations to be conducted that assisted the definition of functional improvements for the further pilot trials.

The unexpected withdrawal of Robosoft from the project presented some difficulties to the final integration tasks that have affected the Phase 1 Pilot Trials. This document is an update of D7.1 which was produced shortly after the withdrawal of Robosoft from the project and represents an incremental update of that report.

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1. Introduction

This report details the outcome of the integration work carried out within WP7.1 and the resulting MARIO system that has been delivered to the Phase 1 trials at each of the three pilot sites. The report details the final Phase 1 trials configuration.

The key outcome of the work leading to the functionality described in this report is a MARIO robot system that was used to assess how well People With Dementia (PWD) can interact with, and benefit from, robot delivered support functions. The trials were also used to assess any changes needed in the MARIO functionality in order to improve the assistance that can be provided to PWD.

1.1. Work Package 7 Objectives

The main objectives of Task 7.1 that are covered by this report were as follows:

- The maintenance and updating of inter-organisation interface specifications established in WP1;
- The on-going step-wise integration of software modules developed in WP4, WP5 and WP6 to test achieved functionality while supporting an iterative development approach;
- The final integration of software and hardware modules on the first prototype systems;
- Full system testing;
- Roll-out of integrated systems;
- Production of an operations manual for the pilot sites. This will be presented in Deliverable D7.3.

This report focuses primarily on the output of the tasks to meet the first 5 of the above objectives, although the penultimate section summarises some of the processes involved.

1.2. Purpose and Target Group of the Deliverable

The purpose of this deliverable is to identify the functional state of the robots being used in the Phase 1 trials and to form a baseline against which further functional improvements can be made. The target groups for this deliverable are:

- The pilot site staff: so that they may understand the functionality available within the Phase 1 trial;
- The MARIO system developers: so they have a record of the functionality delivered into the Phase 1 trials against which iterative improvements can be made;
- The wider community: so that they can see the capabilities of the MARIO system being trialled.

1.3. Relations to other Activities in the Project

As stated above, this report documents work integrating the outputs of WP4, WP5 and WP6. The documented work primarily feeds the Phase 1 trials of WP8 although it also inputs to the follow on iterative development work in the later stages of WP7 (Tasks 7.2 and 7.3).

The baseline document for this report is D1.1, the MARIO system specification document for Pilot 1. D1.1 details the intended system for the Phase 1 trials as conceived at the end of the

requirements definition work. In contrast, this report, and its predecessor D7.1, detail the delivered system based upon changes from the baseline resulting from a combination of factors but primarily those of achievable results given the resources and the actual difficulty of the task, some improvements to the manner in which functionality was achieved and some changes in the requirements following early trialling with PWD.

1.4. Document Outline

The following two sections of the report provide a description of the system hardware and system software architecture developed for the Phase 1 trials, particularly noting differences from those detailed in D1.1. Section 4 provides a review of the major functionality available within the MARIO system and is the primary description of what is being delivered into the trials. Section 5 gives an overview of the processes used during Task 7.1 to achieve the integration. Finally there is a conclusions section providing a summary of the overall activity to date.

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. System Hardware

This section summarises the status of the major hardware components delivered to support the Phase 1 Pilots.

The system consists of the MARIO KOMPAĀ robot platform, which is a wheeled robot approximately 1.5m in height shown in Figure 1 below. The torso and head give the robot a friendly, human-like appearance. The driven wheels are the two at the side which, as well as providing forward and backward motion give the robot the ability to swivel around its vertical centre point or to perform more gradual turns. The front and back wheels are passive castors which provide stability.

MARIO has a range of sensors for sensing the environment and people, including several laser sensors at floor level and a Microsoft Kinect 3D camera fitted at the top of its torso.

The MARIO platform is equipped with a microphone and speaker to facilitate two-way voice communication while the touch-screen provides a display of the current state and options and an alternative means for the Patient with Dementia (PWD) to enter commands and requests. The communication system on MARIO has been designed to be user friendly bearing in mind the mental and sensory capabilities of the range of people with dementia.



Figure 1: MARIO KOMPAĀ Robot

The MARIO hardware architecture is shown in outline in Figure 2 below. There are 3 primary computers on board: a low level system (the PURE computer) primarily controlling the motors and safety system; a Windows PC which primarily controls the interface to people and the outside world; and a Linux PC which hosts the MARIO applications designed for PWD.

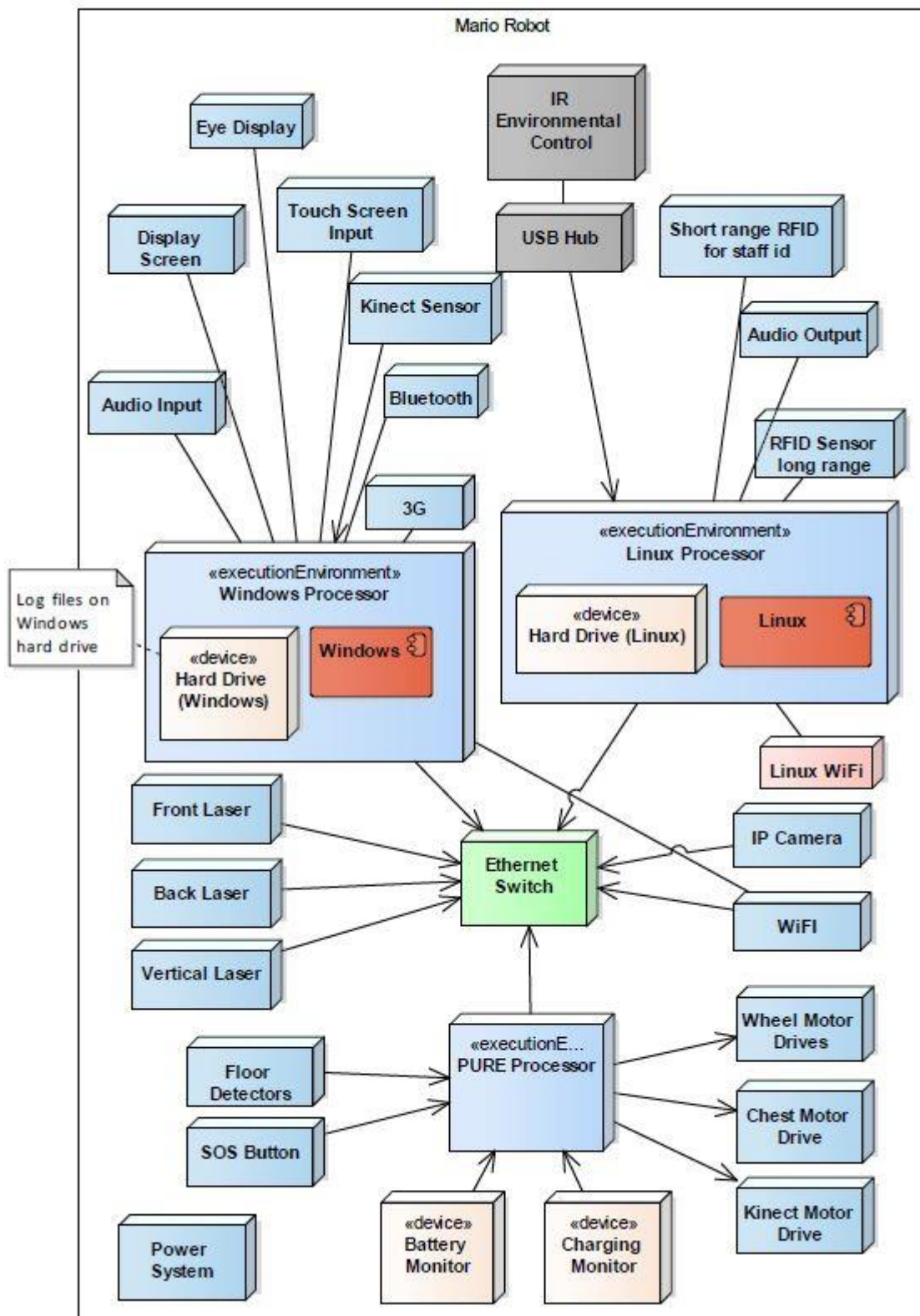


Figure 2: MARIO robot hardware architecture

2.1. Major hardware components

The primary system hardware identified in D1.1 was:

- The robot;
- A charging station;
- A health monitor per person;
- Long range RFID (for recognising objects important to the user);
- Short range RFID (for identifying the user).

The status of the delivered hardware is as follows:

Item	Status
Robot	<p>The production of robots is complete with 11 robots manufactured by Robosoft (reduced from 12 as previously agreed with the Commission). However, following a review after Robosoft’s withdrawal it was decided to reduce the number of robots to 2 per pilot site plus another 2 to support development (8 in total). This decision was partly due to the fact that, despite reporting that the robots were complete, there seemed to be difficulties at Robosoft completing the deliveries. There was also a re-evaluation of the pilot site requirements.</p> <p>The major hardware changes from the system specification were the elimination of the actuators supporting the rotation of the torso and of the Kinect 3D camera, and the removal of the anti-collision laser. The functionality provided by this laser was to be replaced by Robosoft with the Kinect sensor, although this work was not completed.</p> <p>Other less significant hardware changes to the robot have been the removal of the iPad support dock and the basket. These have been removed as they are no longer seen as necessary to the robot’s support function and indeed the basket could have presented a safety risk if PWD tried to use that to help them stand.</p> <p>A significant problem in the post-Robosoft withdrawal period was the non-availability of source code access for the MARIO software to be provided by Robosoft. This software includes the access to on-board sensors, motor drivers and navigation capabilities. This left the project with difficulties for the Phase 1 trials where the Robosoft developed software was either incomplete or not operating as specified. This then had knock on effects in terms of the functionality that could be deployed during these phase 1 trials. Another problem concerned the fact that the RFID receiver was mounted on the robots without the covering box that protected the board from electromagnetic interferences.</p>
Charging Stations	<p>The charging stations (which allow the robots to auto-dock to recharge) have been built but not delivered. It had been hoped that they would have been delivered in time for a proportion of the Phase 1 trials. However, due to legal difficulties associated with payments and supplies from Robosoft these were not delivered and automatic return to base for recharging was not implemented. However, the robots were</p>

Item	Status
	manually recharged, as necessary using the manual chargers already provided.
Health Monitor	Development of the health monitor has continued with a Fitbit as the first device to be identified for testing. After consultation with the Pilot Sites the implementation of the Fitbit sensors was deferred until after the Phase 1 trials, mainly to allow for assessment of the acceptability of the Fitbit devices for the PWD at the different pilot sites
Long Range RFID	A single range RFID system has been procured and is fitted to the robot system. This covers both the short and long range use mentions in the specification. However, the functionality of the sensor was severely limited by the removal of the shielding box

2.2. Sensing systems

Most of the sensing systems used within the MARIO system are supplied with the platform and changes to the specification have been discussed above. The exceptions are sensors placed in the environment or on persons (ambient sensors). For the Phase 1 Pilots only the health monitoring sensor and the RFID tags were in the specification. However, the use of both these sensors has been deferred to later phases of the pilot trials.

2.3. Communications systems

The communications system external to the MARIO robot consists of a Wireless LAN with a Data connection from the Windows PC on the MARIO robot. The facilities in Ireland and Italy have both been equipped to handle the requisite communications with the MARIO robot. The Phase 1 trials in the UK were carried out in a community setting which is also equipped with the necessary Wi-Fi facilities.

A direct wireless LAN from the Linux system on the MARIO robot is possible but not used since it's not necessary for the functions in Phase 1. Internet Connectivity is provided to the Windows PC and that is all that is needed (for the text-to-speech only, no other data is exchanged to the outside of MARIO). As all Pilots for the Phase 1 trials have WiFi installed there is no need for a 3G/4G connection. Bluetooth will not be used in the Phase 1 trials as this is currently only required to connect to the Fitbit which is not used in Phase 1 trials.

3. Software Architecture

The software within the MARIO system is divided into a 3-layer hierarchy, as detailed in the MARIO system specification document (D1.1) and shown in Figure 1. At the lowest level are the system support functions. The middle layer contains the user interaction system and the top layer consists of a series of discrete applications that essentially deliver the functionality of MARIO to the user. The system is controlled and coordinated by an event driven decision manager (now referred to as the Task Manager) that distributes control between the applications.

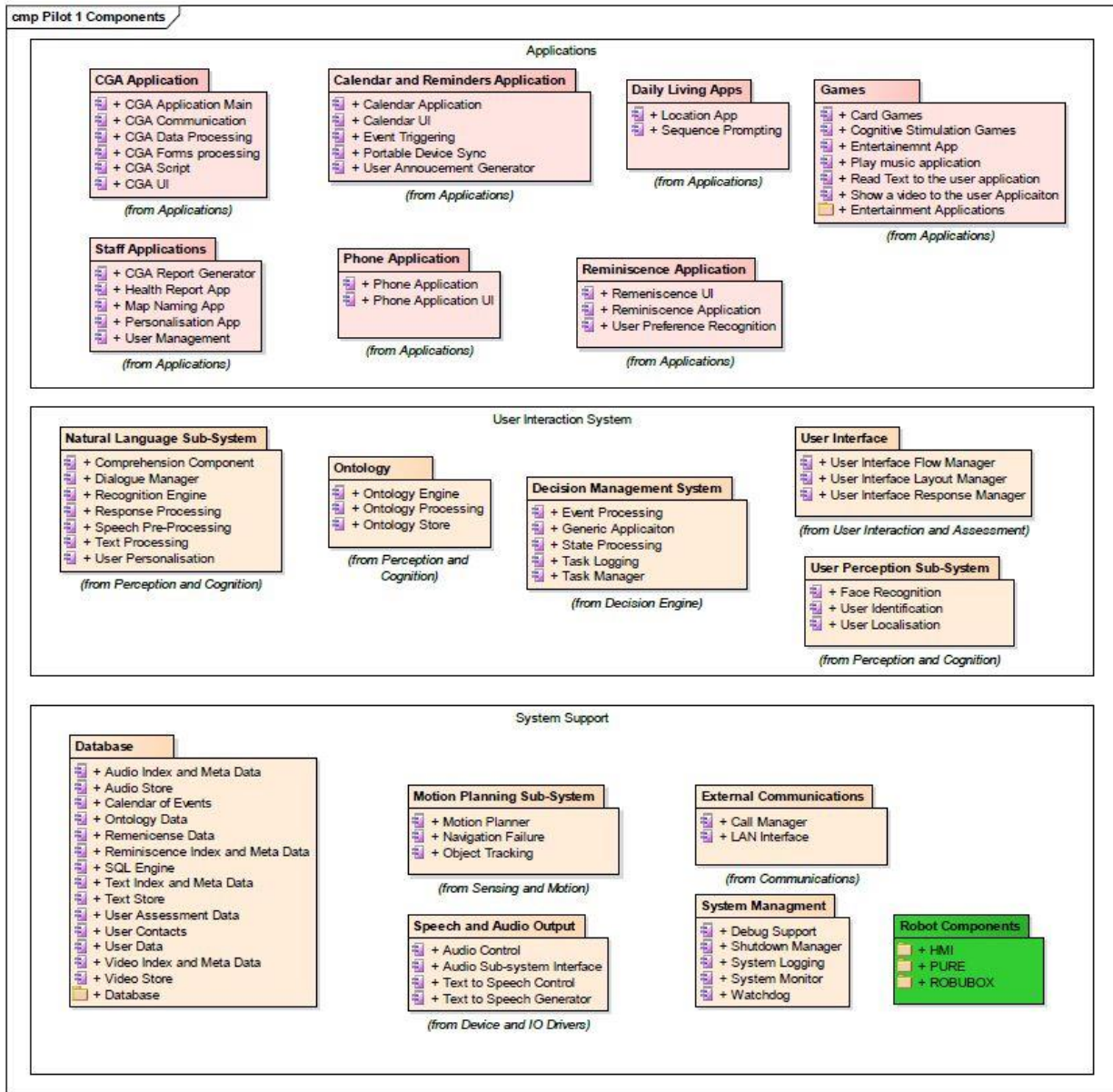


Figure 3: Pilot 1 Package Hierarchy

The software architecture for the Phase 1 Pilots adheres to the architecture in the specification, shown above. The deployed software differs to that of the specification in only four noteworthy ways:

- The number of Applications developed and deployed. Due to a number of factors the number of applications originally envisaged for the Phase 1 Pilots has had to be reduced. This is partly due to the difficulty of the tasks experienced within the

development process versus the resources available but also due to limitations in the underlying MARIO system, particularly in terms of some of the low-level robot system support functions. The difficulties with non-access to the Robosoft source code also had a major impact on the development of functionality for the Phase 1 trials. It is expected that these limitations will be fully addressed in later Phases.

- Although not detailed in the specification, there have also been changes to the interfaces within the architecture particularly between the applications and the low-level robot system. A new interface has been developed to account for both new functionality and the higher data bandwidth resulting from increased use of sensor data by the applications. A further modification to the interface between the applications and the low-level motion controller was planned for the Phase 1 pilots by Robosoft; due to their withdrawal from the project, this and the resulting autonomous motion capability was not completed at this stage and the interactions during the Phase 1 pilot trials were restricted as a result, i.e. there was no approach behaviour prior to initiating user engagement.
- The User Perception Sub-system which allows the MARIO robot to identify users for the purposes of moving towards them and engaging with them was not yet ready at Phase 1. However, as the robot did not have autonomous motion capability, this did not otherwise inhibit the behaviour of the robot.
- The Motion Planning Sub-system was adapted to become the Perceptual and Motor Sub-system and performs the following significant functionality:
 - Environment perception
 - User approaching
 - User following

4. Achieved Functionality

This section covers the main functionality available for assessment during the Phase 1 Pilots as delivered by the implemented applications. The interface to the applications is implemented via voice commands and through a touch screen, which can be used independently of each other.

4.1. Available Applications

Not all of the applications envisaged in the specification for the Phase 1 Pilots have been implemented at this stage. This is primarily due to a combination of task difficulty versus the resources available and the available support functionality within the MARIO system which is primarily impacted by the withdrawal of Robosoft. However, the applications that were available allowed the Phase 1 Pilots to assess the relative utility of a range of applications and help-guide the development for later pilots.

The applications available for the Phase 1 Pilots are:

- Entertainment;
- Games;
- My news;
- Reminders and events.

4.1.1 Entertainment

The purpose of the Entertainment application is to provide tailored entertainment to the user. Currently this consists of playing music to the PWD on request. Care staff can tailor the music available to the PWD. The music application operates through either voice commands or touch screen. The main functions available to the PWD are:

- Selection of music by type
- Skip currently playing track
- Start and stop music
- Change volume
- Through the tests performed in Trial 1 the result gathered from end user's feedback suggested that the apps should be simplified even further, as the type or track selection process is difficult for the moderate dementia patients. The app then has been parametrised so that it can skip the selection process and play the following music track. This configuration is independent for each user so that functionality is personalized based on users capabilities.

4.1.2 Games

The purpose of the games application is to allow the PWD to select and play a series of games such as card games. The main functions available to the PWD were:

- Selection of game
- Reading instructions on how to play the selected game
- Play another game or terminate

However, feedback from users suggested that reading the instructions was an unnecessary step in many cases and so it was removed.

4.1.3 My News

My news is an application that provides a customised news feed based on selected RSS feeds which reflect the PWD's location and interests. The PWD is able to ask for news and for select a specific topic.

4.1.4 Reminders and Events

The purpose of the Reminders and Events application is to provide a handy diary and reminder function to the PWD. The Reminder and Events application allows Care Staff (and Family and Friends) to enter events onto the user's calendar. The MARIO system will inform the user of upcoming events at a pre-determined time. The PWD can query their own calendar in terms of seeing events for the current day or upcoming events in general.

4.1.5 MARIO Configuration

For the Phase 1 Pilots the MARIO configuration is undertaken through a series of ad-hoc scripts and configuration files.

4.1.6 Unimplemented Applications

For the Phase 1 pilot trials the following applications were not implemented:

- CGA Application;
- My Chat (Phone) Application;
- Reminiscence Application;
- My Friends and Family Application;
- Daily Living Application.

Furthermore, due to the lack of mapping, location and user recognition capabilities applications were performed with no autonomous movement capabilities, i.e. no user approach behaviour.

4.2. MARIO User Interaction System

The MARIO User Interaction System provides the underlying support to the applications and much of the intelligence of the MARIO system. The main subsystems of the User Interaction System are:

- User Interface;
- User Perception;
- Natural Language understanding and production;
- Ontology;
- Decision Management System.

4.2.1 User Interface

The MARIO User Interface provides a consistent interface that is simple to understand and operate. All commands to MARIO can be given either as speech input or by choosing an appropriate option on a touch screen. This dual approach provides robustness against problems encountered with sentence understanding and, particularly, noisy environments.

4.2.2 User Perception

User identification and localisation was not implemented for the Phase 1 pilot trials due to resourcing issues following Robosoft's withdrawal. Instead the trials were conducted with MARIO already present at the PWDs location.

4.2.3 Natural Language Understanding and Production

The natural language sub-system is what powers the speech dialogue between MARIO and the PWD. The understanding system is based on Dragon Naturally Speaking 13 Premium, which performed best in terms of the evaluation criteria of the leading speech understanding packages. This system produces text output that is passed to a semantic parser that corrects misspellings and incomplete sentences before passing the result to the Decision Management System. The sub-system also controls when the microphone is set to listening mode such that MARIO is ready to receive verbal commands. For instance, when MARIO is speaking the microphone is not set to listening mode.

Speech output is produced by a standard Text To Speech (TTS) engine situated in the System Support Layer. In practice this can be configured to use the standard Windows TTS or the TTS in Google Chrome. The system can also be configured to select a voice preferred by the PWD.

4.2.4 Ontology

The ontology sub-system was not fully operational for the Phase 1 pilot trials. However, it does provide the knowledge base underlying the natural language processing system.

4.2.5 Decision Management System

The decision management system is the central hub of the MARIO system that processes events and assigns tasks to the various sub-systems and applications based upon the current goals of MARIO.

4.3. System Support Layer

The System Support Layer provides the basic input / output, storage and robot functionalities for the higher layers of the MARIO system. The main functions of the support layer are:

- Database functions
- Motion Planning Sub-system
- Speech and Audio Output
- External Communications

- System management
- Robot Components

4.3.1 Database Functions

A variety of database functions are provided on the MARIO system spread across both the Windows PC and the Linux systems. These provide configuration data, user specific data and preferences as well as supporting the MARIO knowledge base.

4.3.2 Motion Planning Sub-system

The motion planning sub-system was not ready for the Phase 1 Pilot trials due to difficulties encountered with Robosoft mapping and navigation software and due to the unavailability of the API enabling access to sensory states.

4.3.3 Speech and Audio Output

The speech and audio output system provides the text to speech functionality of the MARIO system as well as allowing music and recorded speech to be played.

4.3.4 External Communications

The main functionality provided to the Phase 1 Pilot trials is the LAN and WiFi interface. The Call handler for telephony was implemented but not used in the Phase 1 Pilot trials.

4.3.5 System Management

The functions of system management provided for Phase 1 trials were the Shutdown capabilities, the Debug Support (allowing remote debugging) and the Watchdog. Logging capability was implemented but not utilised during the Phase 1 Pilot Trials.

4.3.6 Robot Components

The robot components provide access to both the motion capabilities of MARIO and the low-level sensors, such as the anti-collision sensors. Due to the non-access to the Robosoft source code, while the basic functionality was available, this could not be modified such that it was decided not to undertake motion behaviour during the Phase 1 trials.

5. Integration Activities

Task 7.1 consists of the integration of the outputs of the technical partners in order to deliver a first version of the MARIO system to each of the pilot sites. The major activity covered has been the integration and testing however maintenance of the major inter-partner interfaces and the production of user documentation has also been covered within this task.

The maintenance of major (i.e. inter-partner) interfaces has been carried out largely on a bi-lateral basis within the project but with regular monitoring and review by the Project Management Team (PMT) both with weekly telephone conferences and with as-needed physical meetings.

The development process adopted within the project is distributed amongst the various technical partners. The integration activities have been incremental and also, to a certain extent, distributed (i.e. both Robosoft and CNR had direct access to a MARIO robot on-site and could therefore perform partial integration tests). Due to the withdrawal of Robosoft at a critical point of the project a final integration and sign off by them was not undertaken. Instead, the majority of the integration was undertaken at CNR with R2M leading the integration testing. NUIG and the other pilot sites providing additional testing and verification of achieved functionality.

There is the facility to remotely deploy updates to each of the sites which will allow both upgrades and bug fixes to be implemented during the pilot trials. It had been intended to roll-out updates following functional testing at Robosoft. However, this testing will now be undertaken by technical partners either with direct access to a robot on-site or at one of the pilot sites, before distribution to the other sites.

An operating manual was produced by Robosoft.

At least one MARIO robot has been delivered to each of the pilot sites and initial commissioning has been undertaken.

6. Conclusions

A first version of the MARIO system has been produced which allowed the MARIO system to be used with PWD in order to evaluate the effectiveness and utility of the functionality provided and provided the baseline against which further incremental development needs can be established.

The MARIO robot was delivered to each of the pilot sites and has been commissioned.

The withdrawal of Robosoft from the project has presented significant difficulties in terms of incomplete functionality that have not been capable of being fully resolved for the Phase 1 Pilot trials. Various alternatives and work-rounds are being implemented to resolve as many of these issues as possible by the final pilot trials.