D4.3 MARIO Robot CGA Module

Project Acronym:	**MARIO**
Project Title:	**Managing active and healthy aging with use of caring service robots**
Project Number:	**643808**
Call:	**H2020-PHC-2014-single-stage**
Topic:	**PHC-19-2014**
Type of Action:	**RIA**

D4.3

Work Package:	*WP4*	
Due Date:	M22	
Submission Date:	30/11/2016	
Start Date of Project:	01/02/2015	
Duration of Project:	36 Months	
Organisation Responsible of Deliverable:	Ortelio Ltd	
Version:	2.0	
Status:	Final	
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Nature:	☐ R – Report ☐ P – Prototype ☐ D – Demonstrator ☒ O - Other	
Dissemination level:	☒ PU - Public ☐ CO - Confidential, only for members of the consortium (including the Commission) ☐ RE - Restricted to a group specified by the consortium (including the Commission Services)	
Project co-funded by the European Commission within the Horizon 2020 Programme (2014-2020)		

Revision history			
Version	**Date**	**Modified by**	**Comments**
0.1	31/10/2016	Alexander Gkiokas, Ilias Trochidis (Ortelio)	Initial document outline and structure
0.2	07/11/2016	Alessandro Russo (CNR)	Added IRCCS contribution on CGA and MPI
	11/11/2016	Alessandro Russo (CNR)	Requirements
	17/11/2016	Alessandro Russo (CNR)	Initial technical description of the module
0.5	21/11/2016	Alessandro Russo (CNR)	Software components with R2M and CNET contributions
	23/11/2016	Alessandro Russo (CNR)	Figures updated
0.8	24/11/2016	Alessandro Russo (CNR)	Integrated CNR contribution on observation-based tests
1.0	25/11/2016	Alessandro Russo (CNR)	Executive Summary and Conclusions; minor changes and refinements for review
	28/11/2016	Maria Kagkoura (R2M)	Feedback on v1.0
1.1	29/11/2016	Alessandro Russo (CNR), Massimiliano Raciti (R2M)	Added Annex 1 as per reviewer's comment
2.0	30/11/2016	Alessandro Russo (CNR), Massimiliano Raciti (R2M), Ilias Trochidis (Ortelio)	Minor edits for final version

Executive Summary

This Deliverable (D4.3) describes the design and development of a robotic module for Comprehensive Geriatric Assessment (CGA), representing the 4Connect+ Medical Community Module. It identifies the fundamental requirements, provides a reference software architecture, and outlines the approaches and technical solutions that are being implemented and investigated to support the execution of questionnaire-based and observation-based assessment tests.

The CGA module presented here aims at enabling the MARIO Kompai robot to autonomously perform and manage the execution of specific tests required in the CGA process, in order to assist the formal caregivers and physicians in the multidimensional assessment phase and facilitate the evaluation of the Multidimensional Prognostic Index (MPI).

This work is the result of a multidisciplinary interaction and collaboration process and the CGA module was designed following a requirements-driven and user-centered approach. The software components discussed in this document are integrated in the overall MARIO software framework and will be deployed in pilot settings (at IRCCS-Italy and NUIG-Ireland) for an initial validation trial starting from January 2017. According to an iterative methodology adopted throughout the project, validation feedbacks are expected to contribute to the refinement and continuous evolution of the CGA module.

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1. Introduction

This deliverable provides an interim report on the design and development of a robotic module for Comprehensive Geriatric Assessment (CGA), representing the 4Connect+ Medical Community Module. The CGA module presented here aims at enabling the MARIO Kompai robot to autonomously perform and manage the execution of specific tests required in the CGA process, in order to assist the formal caregivers and physicians in the multidimensional assessment phase and facilitate the evaluation of the Multidimensional Prognostic Index (MPI).

The work presented here, mainly resulting from the activities carried out in "*Task 4.3: Development of a robotic module to detect health status and increase acceptance*", identifies the main requirements for a robotic CGA module, provides a reference software architecture and outlines the approaches and solutions that are being implemented for supporting the execution of both questionnaire-based and observation-based tests that contribute to a multidimensional patient assessment. In line with the Pilot management processes and procedures defined in Work Package 8 for validation and trial activities in the three different pilot sites (NUIG-Ireland, IRCCS-Italy, and Stockport-UK), the CGA module will be first deployed and validated during Trial 2 in Phase 1 of the Pilot protocol (January 2017) at IRCCS in a hospital setting and, with some limitations due to the peculiarities of the nursing facility setting, at NUIG.

1.1. Work Package 4 Objectives

The overall objective of Work Package 4 is to investigate advanced robotic solutions for Comprehensive Geriatric Assessment (CGA) and determination of Multidimensional Prognostic Index (MPI), with the aim of introducing service robots as a tool for CGA and enabling the multidimensional evaluation of subjects considering the domains of cognitive, nutrition, comorbidity, basal and instrumental activities of daily living. Specifically, the objectives of WP4 are the following:

- customization of the comprehensive geriatric assessment (CGA) approach to the service robot context;
- selection of the technologies that could be more adequately fitted on the MARIO platform starting from the specific user needs of the elderly;
- definition of a Multidimensional Prognostic Index (MPI) capable to dynamically detect the health changes occurring in a subject living at home or in hospital;
- development of a CGA module for the robotic platform, through a multidisciplinary interaction using a user-centered design approach.

This deliverable specifically contributes to the achievement of the last objective listed before, as part of the activities of "*Task 4.3: Development of a robotic module to detect health status and increase acceptance*".

1.2. Purpose and Target Group of the Deliverable

The purpose of this deliverable is to describe the design and development of the CGA module that constitutes the 4Connect+ Medical Community Module of the MARIO software framework. In particular, this deliverable aims at:

- identifying the fundamental requirements for the design and implementation of a robotic CGA module able to assist the clinician in the assessment process by autonomously executing selected tests;
- providing a reference software architecture for the CGA module, integrated with the robotic platform and the other components of the MARIO software framework;
- reporting on the approaches and technical solutions that are being implemented and investigated to support the execution of questionnaire-based and observation-based assessment tests;
- outlining the basic capabilities of the CGA software module that will be deployed and validated with end users as part of the Pilot protocol defined within the project.

This deliverable is thus targeting heterogeneous parties and stakeholders interested or involved in a robotic CGA module for service robots. Software architects and robotic experts are provided with a technical description of the requirements, the architectural models and the implementation solutions that enable a mobile robot to autonomously undertake a CGA. Caregivers and health professionals (including care staff in the selected pilot sites) can increase their understanding on the role and potential benefits of service robots in supporting the CGA process.

1.3. Relations to other Activities in the Project

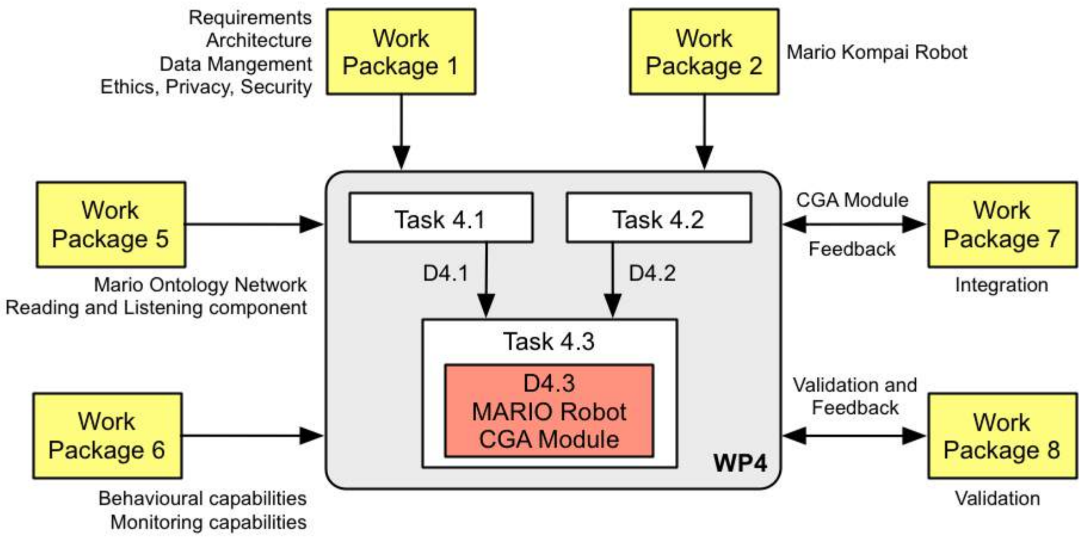

Figure 1: Relationships between D4.3 and other activities

The main relationships between this deliverable and the other tasks and Work Packages in the project are shown in Figure 1. D4.3 directly takes as input the comprehensive analysis of the different CGA domains, carried out in Task 4.1 and reported in Deliverable 4.1, and the Multidimensional Prognostic Index defined as part of Task 4.2 and presented in Deliverable 4.2. The CGA Module takes into account the user and functional requirements and the system architecture from WP1, as well as the principles defined for data management and for the ethics framework that impact on security and privacy. WP2 provides the Kompai robot and platform where the CGA module is deployed. WP5 contributes with the Mario Ontology Network (MON) and with the natural language understanding capabilities, while WP6 provides as input the motion behavioural capabilities and the user monitoring components. The CGA Module is integrated in the MARIO framework in the integration process managed by WP7, while it will be validated according to the methods and procedures defined in WP8. Integration and validation activities in turn provide feedback to the iterative design and development process of the CGA Module and will contribute to its evolution and refinement.

1.4. Document Outline

This document is structured as follows. Section 2 provides an overview of the Comprehensive Geriatric Assessment process and characterizes the different tools used for a CGA. The general requirements for a robotic CGA module are then identified in Section 3. Section 4 introduces the design and development process that has been adopted and the details the reference software architecture and its components, designed to support the execution of questionnaire-based and observation-based CGA tests. Security and privacy aspects are considered as well, along with the actual development status, the scheduled validation activities and long-term evolution of the CGA module. Section 5 finally concludes the deliverable, while the assessment tools used in a CGA

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. Background and Motivation

The Comprehensive Geriatric Assessment (CGA) is a multidimensional and interdisciplinary diagnostic process and instrument, part of a clinical management strategy that aims at addressing the issues related to frail elderly patients. CGA procedures provides a reference framework designed to collect and analyse data to determine the medical, psychosocial, functional and environmental status and problems of an elderly patient, with the goal of defining an overall, personalized plan for treatment, follow-up and long-term care. Evidence-based observations confirm the expected benefits coming from the adoption of CGA protocols, including improving the diagnostic plan and the diagnostic tests selection process, creating individualized and proportional treatment plans, reducing risks and complications (and thus mortality) during the hospitalization period, and increasing the patient's functional autonomy after discharge.

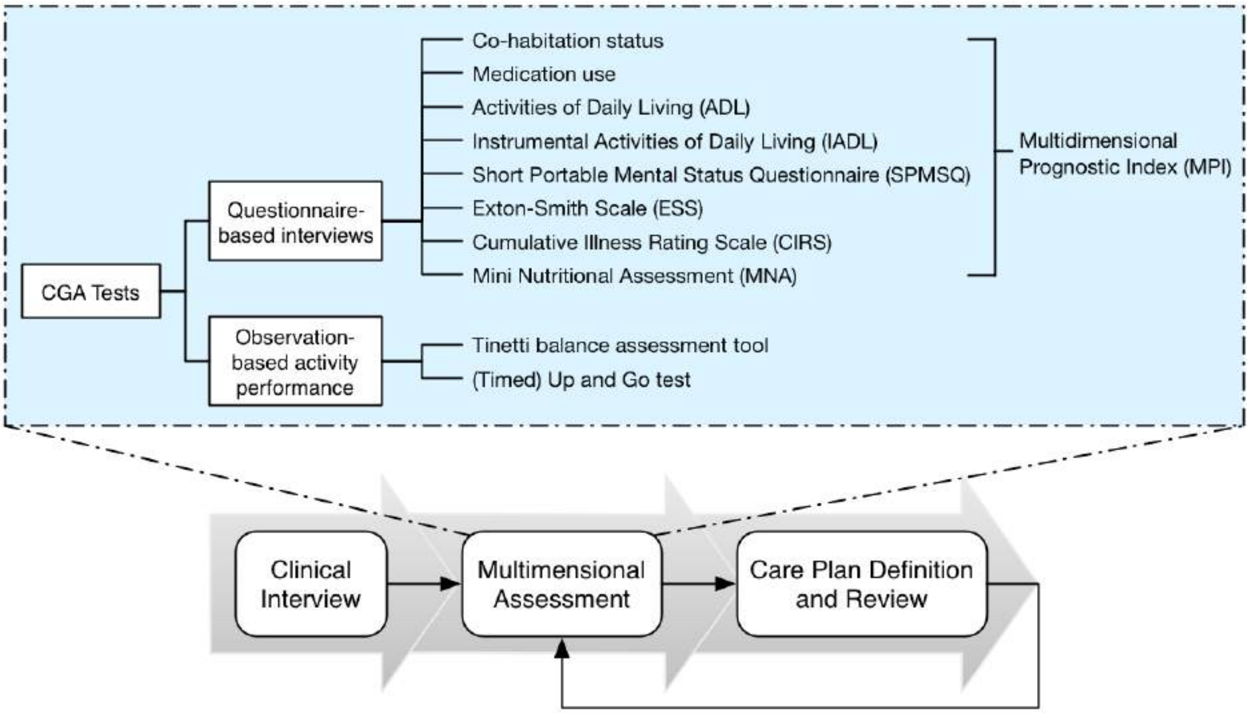

Figure 2: CGA Process and Assessment Tools

identifying patient’s functional problems and disabilities, to a more complete and in-depth evaluation of these problems usually coupled with therapeutic plans assessed and defined by an extended multidisciplinary team of social and clinical geriatric professionals. Regardless of the specific setting, CGA procedures conceptually include three main phases, as shown in Figure 2 and summarized in the following.

1. **Clinical Interview.** During the initial clinical interview the physicians gather preliminary information about patient's health status, by interacting with the patient and his/her relatives.
2. **Multidimensional Assessment.** During this phase, data-gathering and assessment activities are undertaken, by performing reference multidimensional tests to evaluate the functional, mental and social status of the elderly patient.

3. **Care Plan Definition and Review.** In this phase, the data gathered in the previous phases contributes to the definition of a patient-specific care plan (with diagnostic tests, therapeutic recommendations, etc.) to be implemented. Patient's adherence and response to the care plan is monitored over time and this leads to periodically repeat the multidimensional assessment tests, whose results are compared with the previous execution in order to identify an improvement or deterioration in patient's status and revise the care plan.

The multidimensional assessment phase is at the heart of the CGA process and represents a critical, time consuming activity for the caregivers. In order to gather information about the patient, physicians rely on a set of widely accepted, internationally validated formal assessment tools and standardized rating scales designed to evaluate patient's functional abilities, physical and mental health, and cognitive status. CGA tests allow gathering quantitative information to objectively evaluate patient's status, and can be generally classified in two main classes.

- *Questionnaire-based tests:* on the basis of standardized clinical questionnaires, the patient is required to answer some questions (e.g., about his/her daily life and ability to autonomously perform specific activities). Depending on the answers, a score is given to the patient and evaluated according to a reference rating scale. Specifically, eight assessment tools (listed in Figure 2) are currently used as part of a CGA.
- *Observation-based activity performance tests:* the patient is required to perform specific physical activities (such as getting up and walking for a short path) related to gait/balance assessment and fall risk assessment. The patient is evaluated by observing the execution and rating his/her performance according to a reference scale. The Timed Up and Go (TUG) test [1] and the Tinetti Balance Assessment Tool [2] can be considered as representative examples of this kind of tests.

The multidimensional assessment carried out as part of a CGA enables the evaluation of a Multidimensional Prognostic Index (MPI). The MPI represents a prognostic tool, based on a standard CGA, that predicts short- and long-term mortality in elderly subjects. The MPI combines and aggregates the scores resulting from the eight different domains of CGA, in order to derive a single score able to synthetically represent the health status of a person and define the severity grade (low, moderate, severe) of mortality risk [3] [4] [5]. The eight assessment tools used in a CGA and their contribution to the MPI are available online in both English[1] and Italian[2], and are provided in Annex 1 – CGA and MPI Assessment Tools.

The assessment varies depending on the specific care setting (long-stay care facilities, nursing homes, hospital care settings, etc.) and collected information must be updated periodically to enable a quantitative evaluation of patient's evolution. A CGA is typically carried out every 6 months and the actual duration of an assessment session depends again on the care setting where it is performed. On average, a questionnaire-based evaluation session requires between 20 and 30 minutes per patient to be completed, and the duration increases up to an hour or more for a comprehensive evaluation. As most of the total time available to the formal caregiver is

[1] http://www.operapadrepio.it/contenuti/ricerca/pdf/TEST_MPI_en.pdf

[2] http://www.operapadrepio.it/contenuti/ricerca/pdf/TEST_MPI.pdf

consumed to collect information from the patient, the evaluation and definition of a personalized care plan is often performed under time pressure, in particular in the setting of an ambulatory geriatric care unit. In addition, the CGA process may not be completed in one session and further sessions are required to continue and complete the assessment.

Nowadays health professionals increasingly use ICT supporting tools and devices (such as computers and tablets) during the multidimensional assessment phase for recording test results and calculate the corresponding scores. However, it has been observed that these devices and the need to interact with them to input information can represent a "communication barrier" between the caregiver and the patient during clinical interviews [6]. The lack of visual contact with the caregiver can further increase stress and anxiety in frail elderly patients undergoing a cognitive evaluation whose results may potentially impact on their autonomy. Specific software applications are available for supporting the clinicians in the evaluation and calculation of the MPI and related scores, such as the Calculate-MPI tool[3] and the iMPI application for iOS-based devices[4]. In addition, as a consequence of the ECHORD++ challenge focused on Robotics for the Comprehensive Geriatric Assessment [6], the ASSESSTRONIC project[5] and the CLARC[6] framework [7] are currently investigating mobile robotic solutions for supporting the CGA process.

MARIO's CGA module aims at enabling the robot to autonomously perform and manage the execution of specific tests required in the CGA process, in order to assist the formal caregivers and physicians in the multidimensional assessment phase and facilitate the evaluation of the Multidimensional Prognostic Index. The introduction of a robotic solution able of autonomously performing parts of a CGA is expected to reduce the direct involvement of health professionals in the time-consuming data collection tasks, as well as the perceived tiredness resulting from the performance of repetitive tests. As a result, this will enable them to concentrate their efforts on the interpretation of the results and the elaboration of personalized care plans. In the long term, the objective is to enable a continuous monitoring over time of the different aspects or domains that contribute to the assessment of patient's conditions, with an opportunity to early detect relevant changes in the health status.

[3] http://www.ulss16.padova.it/all/MPISetup.exe

[4] https://itunes.apple.com/it/app/impi/id485754422?mt=8

[5] http://echord.eu/essential_grid/assesstronic/

[6] http://echord.eu/essential_grid/clarc/

3. General Requirements

MARIO's CGA module addresses specific requirements that extend or specialize the broad set of requirements identified for the MARIO software framework and detailed in Deliverable 1.1 [8], along with reference use cases. Technical and non-technical requirements were thus derived from reference scenarios and use cases, taking into account interviews with the care staff at the different pilot test sites and audio/video recordings related to the performance of questionnaire-based CGA tests in clinical settings.

By exploiting the underlying robotic platform and its sensors and I/O devices, the CGA module is generally required to enable the MARIO robot to manage autonomously the execution of some tests of a CGA, assisting the health professionals in the data collection and assessment process that leads to the construction of the Multidimensional Prognostic Index. To this end, the robotic CGA module is required to:

- allow the authorized caregivers to select and configure the tests to be performed for a specific patient or in a specific setting, including the option to skip/remove single questions that do not apply in a given healthcare setting;
- undertake a dialogue-based interaction with the patient to perform questionnaire-based selected tests, including the ability to:
    - pose questions and acquire the answers using speech, with multi-language support;
    - understand and interpret patient's answers provided in spoken language using natural language processing;
- complement the natural language interface with a graphical user interface and touch-based interaction modality to gather patient's input;
- codify and record patient's answers, assigning the corresponding score, and calculate tests scores as per tests specifications;
- record and evaluate patient's performance during physical tests, using motion tracking and analysis to derive performance parameters and score the results;
- generate health reports for the care staff and provide the authorized caregivers with a dashboard-like interface that allows them to access, analyse and review test results, with the possibility to modify/correct test scores.

4. Application Design and Development

The CGA application represents one of the main abilities of the MARIO application suite. It is designed following a requirements-driven and user-centered approach to enable the robot to autonomously perform an assessment process in order to collect data on the mental and functional capabilities of the patient.

4.1. Design and Development Process

The design and development process adopted for the CGA module follows the basic principles taken into account in the design and development of the robotic applications that constitute the 4-Connect My Hobbies module, presented in Deliverable 3.4 [9]. Achieving the overall goal of automating parts of the execution of a CGA through the MARIO robot requires an *incremental* and *iterative* design and development approach, inspired by Agile principles. The design and development strategy for the CGA module aims at gradually adapting, extending and improving the available features and capabilities on the basis of a continuous assessment process driven by trial results. According to overall pilot plan for MARIO validation activities defined in Deliverable 8.1 [10], the CGA module will be first deployed and validated during Trial 2 in Phase 1 of pilot activities, i.e., in January 2017. Given that user acceptability is fundamental and represents at the same time a critical success factor and a major potential obstacle, the initial application design and development aims at providing the core functionalities that enable the robot to autonomously perform parts of a CGA, operating under the control and supervision of the care staff. This primarily includes the ability to initiate and undertake a questionnaire-driven dialogue with the patient, as well as the ability to track and monitor his/her motion behaviour under specific constraints and execution settings. However, no specific constraints are imposed to the patient and the proposed solution is expected to operate in the typical settings of a clinical encounter where the interaction process is driven by the health professionals. Since the early stages of the validation phase, the provision of core functionalities will be enriched with the added-value coming from the capabilities of the robotic platform hosting the CGA module. Sensorimotor capabilities are considered as a viable solution for further improving the user experience during the assessment procedures. This includes the ability of MARIO to orient itself towards the user, as well as the ability to dynamically approach the patient and adjust its position and distance depending on the test to be performed. The iterative development circles will build on feedback gathered from pilot trials in order to refine and extend the capabilities of the CGA module, as outlined in Section 4.3.

4.2. Architectural Model and Software Components

The CGA module features a system-clinician interface allowing the caregiver to configure the CGA tests to be performed and review test results. The application is in charge of performing the selected tests and store the corresponding results and scores, by interacting with the patient or observing his/her behaviour. In order to collect data during questionnaires and interview-based tests, both speech recognition and touch-screen interaction modalities are used as part of the robot-patient interface, while body pose and motion tracking and analysis techniques enable the execution of observation-based tests. Data collected by the application then serves as a basis for a multidimensional assessment performed by the caregivers.

The CGA module relies on the **CGA Ontology Module** detailed in Deliverable 5.1 [11] as part of the MARIO Ontology Network (MON). The CGA ontology supports the execution of the assessment process by providing a reference model for storing test information (such as questions, expected answer etc.) and allows storing and recording the data resulting from test executions. Specific ontology sub-modules were designed to capture the peculiarities and requirements of the different tests that compose a CGA. In order to access the ontology and the corresponding data, the CGA module exploits the functionalities and API provided by the MARIO Knowledge Management System described in Deliverable 5.1 [11].

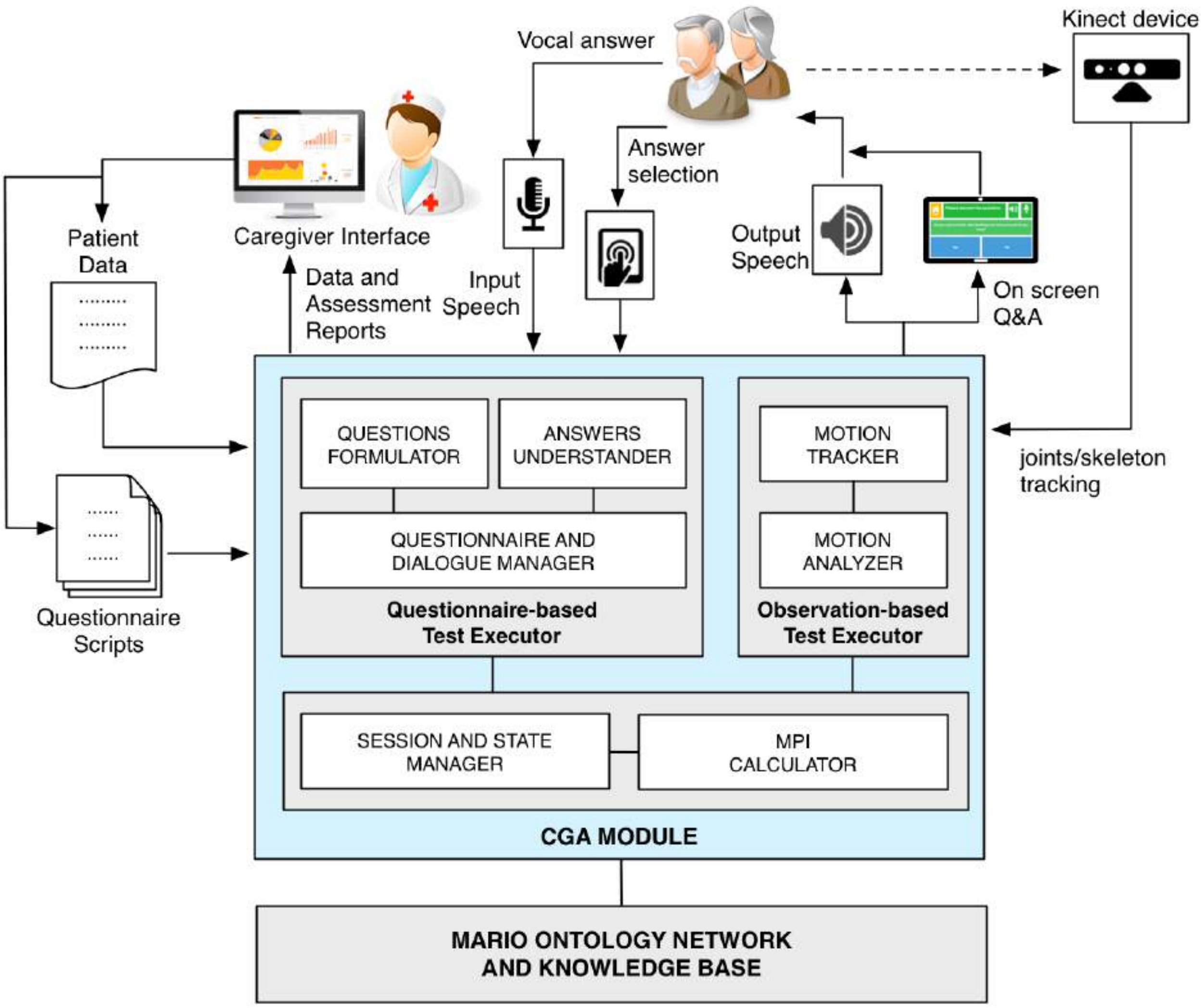

Figure 3: Reference architectural model

The reference architectural model of the CGA module is shown in Figure 3 and the main components are described in the next sections.

4.2.1 Caregiver Interface

The CGA module provides a **Web-based Graphical User Interface**, designed to allow the authorized clinicians to configure patient's profile and CGA sessions, trigger and monitor their executions, and access generated health reports and scores resulting from the assessments. Although directly available using the touch-screen on the robot, the interface is intended to be accessed by the caregivers through an external device (e.g., a laptop computer or a tablet connected to the robot via a local wireless connection). Standard account-based authentication mechanisms ensure access is limited to authorized care staff members and HTTPS connections protect the privacy and integrity of the exchanged data.

Patient profile required for a CGA can be pre-configured and managed through the interface by a designated caregiver. The minimum set of patient-specific information includes patient's first name, age, sex, and a unique patient identifier (patient ID). The patient ID provides a basic form of data anonymization and is used by the medical staff to link the patient profile managed by MARIO with detailed information and medical records stored in external clinical data management systems. The interface allows the caregivers to select and configure the tests to be performed as part of a CGA (e.g., disabling questions that do not apply to the specific patient or care setting), as well as to start (and stop or suspend) and monitor a CGA session performed by the robot. Through the interface, the clinician can then access recorded answers provided by the patient, test results and calculated scores. Score assignments automatically calculated by the system can be manually edited and reviewed, to allow the clinician to confirm or correct them (e.g., in the case of a misinterpretation of patient's answer to a question). Similarly, the caregiver can provide missing data for tests not performed by the robot but required to calculate the overall MPI. Reports made available to the care staff provide an overview of patient evolution over time, but the system will not attempt to analyse the data from a clinical perspective (e.g., providing medical advice) as this is out of the scope of a non-medical device like MARIO and is thus left to the physicians.

4.2.2 CGA Session Management and MPI Assessment

The **Session and State Manager** manages the overall execution and status of CGA sessions, coordinating the scheduling and performance of the configured tests. It operates on the basis of the user profile and test configuration settings provided by the formal caregiver and available in the *MARIO Knowledge Base*. In line with the overall MARIO control architecture and applications design and development principles, the CGA module operates under the control and supervision of the *MARIO Task and Ability Manager*. The *Session and State Manager* is responsible for interacting with the *Task and Ability Manager* subsystem, according to message-based interaction patterns that: *(i)* allow the *Task and Ability Manager* to control the application (by starting, stopping, suspending and resuming its execution); *(ii)* enable the CGA application to notify status changes. As CGA tests are typically performed during a clinical encounter (e.g., when the patient is admitted to or discharged from the Geriatric Unit), a CGA session can be initiated by the caregiver either through the provided graphical interface or by vocally interacting with the robot, asking MARIO to perform a CGA of the patient. When triggered by the *Task and Ability Manager*, the *Session and State Manager* initiates and monitors the sequential execution of the specific tests to be performed, by interacting with the two main subcomponents responsible for conducting questionnaire-based and observation-based tests.

The **MPI Calculator** is responsible for calculating the overall Multidimensional Prognostic Index, taking into account the scores and rating scales resulting from the execution of the assessment tests. For each of the scores resulting from the eight assessment tools, an MPI severity score is assigned on a three-level scale (low-medium-high), according to the partition shown in Table 1.

Table 1: MPI score assigned to each domain based on the severity of the problems

	MPI severity score for each domain		
Assessment tool	**Low (Value = 0)**	**Mild-moderate (Value = 0.5)**	**Severe (Value = 1)**
ADL	6 – 5	4 – 3	2 – 0
IADL	8 – 6	5 – 4	3 – 0
SPMSQ	0 – 3	4 – 7	8 – 10
CIRS-CI	0	1 – 2	≥ 3
MNA	≥ 24	17 – 23.5	< 17
ESS	16 – 20	10 – 15	5 – 9
Number of medications	0 – 3	4 – 6	≥ 7
Social support network	Living with family	Institutionalized	Living alone
MPI score: *Sum up the scores assigned to each domain, and then divide the sum by 8*			

The overall MPI score is then computed by summing up the eight score and dividing the result by eight. The resulting score is the assessed according to the rating scale reported in Table 2.

Table 2: MPI risk assessment

	Risk		
	Mild	**Moderate**	**Severe**
MPI Score Range	0 – 0.33	0.34 – 0.66	0.67 – 1

4.2.3 Questionnaire-based Test Execution

The **Questionnaire-based Test Executor** is in charge of the execution of questionnaire-driven tests that are part of the assessment process. Test executions are triggered by the Session and State Manager. The Executor is then responsible for engaging the patient in a dialogue-based interaction, with the aim of gathering information that enables the calculation of assessment scores and prognostic indexes. The dialogue flow is driven by the robot (i.e., the interaction is *system-initiated*) and unfolds on the basis of a continuous question-answer interaction pattern. To this end, the component relies on the speech-based communication capabilities provided by the MARIO framework and operates on the basis of scripted representations of the different questionnaires that are part of the CGA (e.g., the Short Portable Mental Status Questionnaire). Dialogue management is driven by the questionnaire structure, which acts as a blueprint for the question-answer interactions and provides the ordering and sequencing of the assessment questions.

For a specific test, the corresponding questionnaire script is derived from its description and representation retrieved from the Knowledge Base. Specifically, a questionnaire is structured as an ordered set of questions, and for each question the following main information is represented:

- one or more question formulations defining the wording to be used by the robot when addressing the user;
- in the case of a closed-ended question, the set of possible answers along with the corresponding score;
- in the case of an open-ended question, the corresponding answer and associated score;
- in the case of a closed-ended question, conditional links to the next question to be posed to the patient when a specific answer is provided (to represent, for example, that in the case of a "yes/no" closed-ended question the subsequent question to be posed may change depending on the user giving a positive or negative answer).

In many cases, the items that compose an assessment and contribute to a rating scale (as in the case of the Activities of Daily Living or Instrumental Activities of Daily Living tools) are not directly provided in the form of questions. A key step in the design of questionnaire-based tests is thus the definition and (multi-language) formulation of appropriate questions to be posed to the patient and their mapping to the items of the reference assessment tool. This task is directly driven by the experience of the caregivers (in particular the care staff operating in the IRCCS and NUIG pilot sites) performing CGAs as part of their daily clinical activity. In particular, where possible, assessment items are mapped to one or more closed-ended questions with predefined answers. Questions are thus formulated in a way that induces a restriction on the answers space. The advantages of this approach are twofold: on one side, providing the user with a limited set of possible answers (typically restricted to "yes/no" options) aims at reducing the cognitive load for the patient in the question-answer process; on the other side, this reduces the interpretation dimensions that have to be considered when natural language understanding techniques are used.

Questions formulation from test items and the ordering of questions induced by answers' types can be better understood through a concrete example. In the table reported below (Table 3), the second item of the Activities of Daily Living (ADL) assessment is reported, which aims at evaluating patient's autonomy in the dressing task.

Table 3: Item definition in the ADL questionnaire for evaluating dressing capabilities

DRESSING (gets clothes from closets and drawers – including underclothes, outer garments, and using fasteners including braces, if worn)	
Option	**Score**
Gets clothes and gets completely dressed without assistance	1
Gets clothes and gets dressed without assistance, except for assistance in tying shoes	1
Receives assistance in getting clothes or in getting dressed, or stays partly or completely undressed	0

The objective is to identify which of the three alternatives better describes the functional capabilities of the patient, so that the corresponding score can be assigned. To this end, the following two questions closed-ended questions are considered:

1. *"Do you need any help when getting your clothes or getting dressed?"*
2. *"Do you need any help in tying your shoes?"*

As summarized in Figure 4, if the patient provides a positive answer to the first question, the assessment logic can conclude that she receives assistance in getting clothes or in getting dressed: this is thus recorded, a score of 0 is assigned to the "Dressing" item in the ADL test and the evaluation can proceed with the next item. If the user instead provides a negative answer to the first question, it is already possible to assign a score of 1 to the item, as she gets clothes and gets completely dressed without assistance. However, a distinction has still to be made between the first and the second alternative in the item. To this end, the second question is asked to the patient: depending on whether a positive or negative answer is provided, the second or the first alternative can be recorded respectively, before moving to the next item in the ADL assessment.

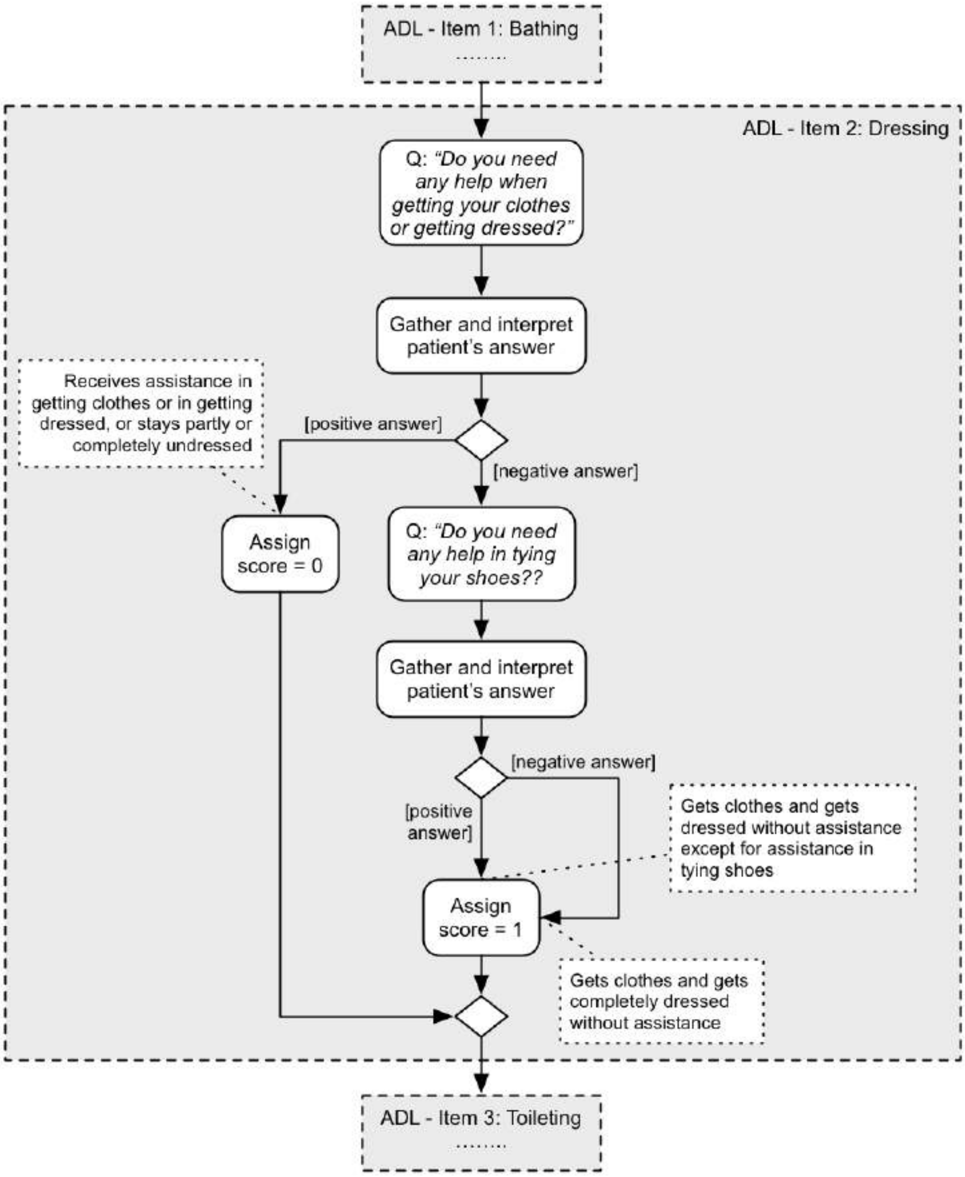

Figure 4: Example of a question-answer interaction process and score assignment

Basically, the app gradually presents spoken questions to the patient and gathers his/her vocal responses to be interpreted. Although vocal interaction is considered as the primary communication mean for both formulating the questions and gathering the responses, a multimodal approach is adopted. Each question formulated by the app and uttered by the robot is contextually shown on the touch screen. Depending on the question type (open-ended or closed-ended question), possible answers may be shown on the screen as well, as shown in Figure 5. This enables the patient (where applicable) to provide his/her answers by directly speaking to the robot or by interacting with the graphical interface. The availability on the screen of possible answers is also affected by the specific questionnaire that is being performed. For example, in the case of potentially closed-ended questions in the Short Portable Mental Status Questionnaire (SPMSQ) for the evaluation of patient's mental status (e.g., "*What day of the week is it today?*") the corresponding answer set should not be provided to avoid introducing a bias in the assessment results. For the same reason, for questions like "*How old are you?*" a restricted set of possible answers to select from is not provided.

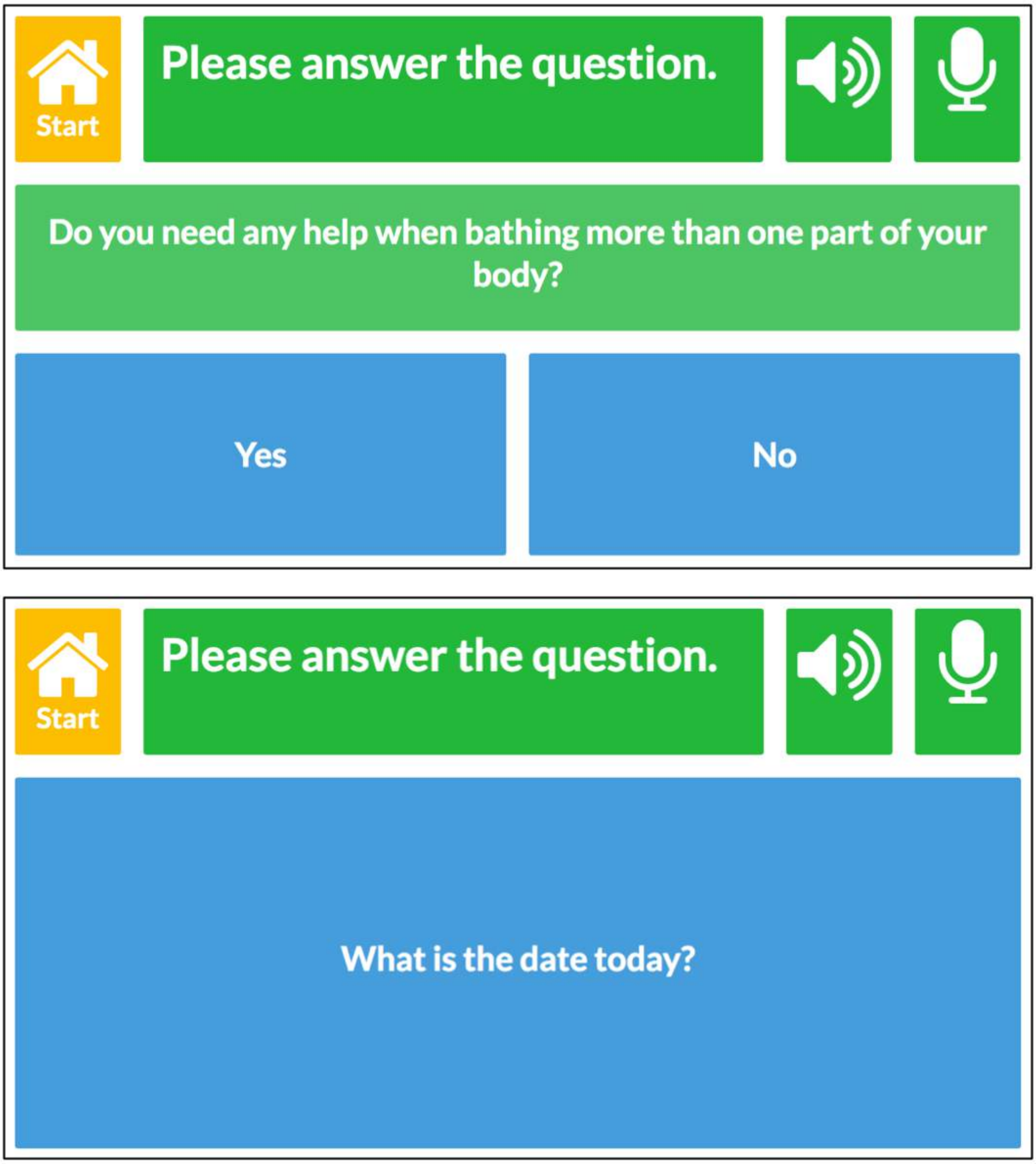

Figure 5: UI screens for closed-ended and open-ended questions

The application internally keeps and updates the dialogue status as the questionnaire unfolds. The CGA app strongly relies on natural language understanding capabilities for interpreting patient's utterances representing answers to the evaluation questions. A proper interpretation of provided answers ultimately results in the assignment of a score to each answer (according to the questionnaire-specific rating scale), which contributes to the calculation of the overall score or index. The language understanding features of the CGA module extend and specialize in the CGA domain the capabilities of the MARIO understanding subsystem (whose capabilities, reference models and design principles are presented in Deliverable 5.2 [12]), with a focus on patient answers interpretation as part of the system-driven questionnaire-based evaluation process. The robot-patient interaction pattern for each question-answer step in a questionnaire-driven assessment test relies on a basic state-based dialogue management strategy, summarized in Figure 6, that complements and refines the process described for the example in Figure 4.

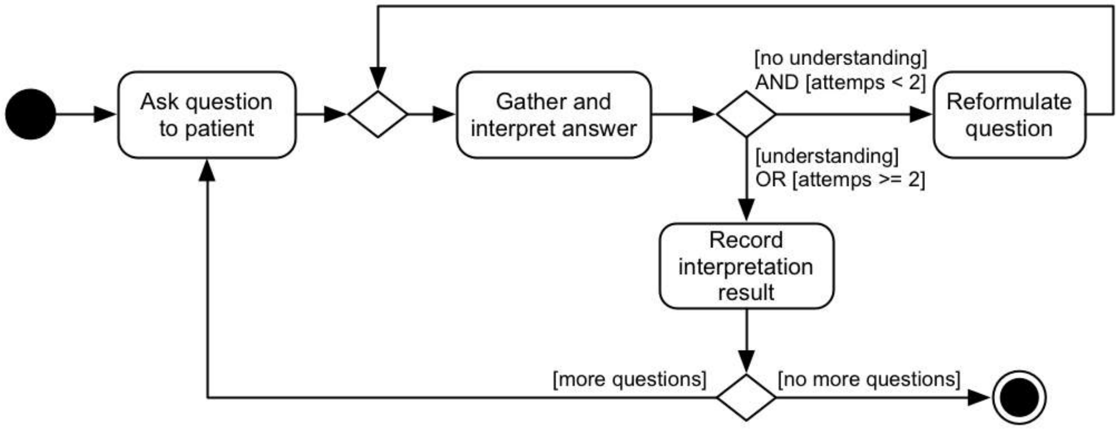

Figure 6: Dialogue management process for a question-answer interaction

Basically, each question in the assessment test under execution is posed to the patient and an attempt is made to interpret the corresponding answer. If the system is not able to understand and interpret the answer, the question is posed again to the patient and where applicable it is rephrased and/or accompanied with suggestions that aim at guiding the patient in providing an answer that can be understood. In the case of an answer that cannot be interpreted and understood, at most two attempts are made to reformulate the question. Multiple attempts without a successful interpretation degrade the interaction experience producing stress and frustration in the patient, and potentially lead to disengagement that prevents the assessment to be completed. After two unsuccessful attempts, the question is left unanswered, the failure is recorded, and the next question is considered (if any), even if this can prevent to assign a score to the corresponding item in the assessment questionnaire. Missing information can eventually be collected and entered by a caregiver in a later stage. Similarly, in the case of a successful understanding of patient's answer, both the answer and the interpretation are recorded (along with the corresponding assessment score if assignable) and the next question is considered.

The answer understanding and interpretation step relies on the layered interpretation approach provided by the MARIO Understanding component presented in Deliverable 5.2 [12]. The CGA *Answers Understander* takes as input the textual representation of patient's utterances, as provided by the MARIO *Speech-to-Text* subsystem. The actual interpretation strategy directly depends on the question classification and corresponding answer type. From the analysis carried out in Deliverable 4.1 [13], it emerged that the usage of a restricted vocabulary and keyword-spotting techniques can be effective in supporting predefined dialogues where the interaction is driven by the system for eliciting specific information from the user through a set of questions, as it is the case in a CGA assessment. By relying on this hypothesis, and on the basis of the interaction patterns observed in the analysed audio/video recordings, the CGA module will be initially deployed, tested and validated in the pilot sites with understanding capabilities based on matching regular-expression patterns against patient's utterances.

Yes-No Questions. In the case of Yes-No questions, which cover most of the items in the CGA questionnaires, patient's answers are matched against regular expression patterns that aim at capturing both positive and negative answers. The patterns were built by exploiting existing linguistic resources, in particular the Paraphrase Database (PPDB)[7], an automatically extracted multilingual database containing paraphrases in 16 different languages (both English and Italian are covered) [14]. Starting from manually defined seeds of positive and negative expressions, the PPDB was queried to include lexical, phrasal and syntactic paraphrases. Although this approach increases the pattern coverage for interpreting positive and negative answers, it still relies predetermined regular expression patterns. To overcome this limitation and extend the understanding capabilities, a transformation and integration process has been undertaken to include the PPDB lexical resource in the Framester knowledge graph and linked data hub [15] (introduced in Deliverable 5.1 [11]) that will be exploited by the Understanding component (outlined in Deliverable 5.2 [12]). This will enable the possibility to dynamically query the resource to retrieve paraphrases in an attempt to interpret answers that do not directly match the defined patterns.

Wh-Questions and other questions. In the case of Wh-questions, which cover most of the items in the SPMSQ questionnaire (e.g., "*What day of the week is it today?*", "*Who is the Pope now?*", "*When were you born?*"), the understanding process maps to the task of comparing patient's answers with known properties of named entities, typically persons (including the patient herself, his/her parents, and well-known present and historical individuals) or places, such as birth date, home address and other personal attributes. These properties can be directly retrieved or derived by querying the MARIO Knowledge Base (e.g., by accessing patient's profile to get his/her birth day and derive his/her age, or his/her mother's maiden name) and then compared with the provided answer. The usage of multiple labels for a given entity and the definition of multiple properties as possible answers for a question can be exploited to improve the recognition (for example, the Pope may be mentioned using his papal name, e.g., "Francis", or his birth name, e.g., "Bergoglio") and multilingual labels/properties are directly supported using the language tagging facility of RDF literals. The matching process relies on specialised understanding functions that restrict the recognition and interpretation to specific domains, such as dates and numbers (used for example when the user is asked to perform basic math calculations as part of the SPMSQ questionnaire).

4.2.4 Observation-based Test Execution

The **Observation-based Test Executor** is in charge of the execution of observation-based tests that require to track and monitor the patient while performing predetermined activities for gait and risk fall assessment. As a reference scenario, execution support for the *Timed Up and Go* (TUG) test is being considered [1]. TUG performance basically aims at evaluating and scoring patient's basic mobility skills by measuring the time (in seconds) the patient takes to rise from sitting from a standard arm chair, walk for approximatively 3 meters, turn, walk back to the chair, and sit down again. Test performance is graphically represented in Figure 7.

[7] http://paraphrase.org/

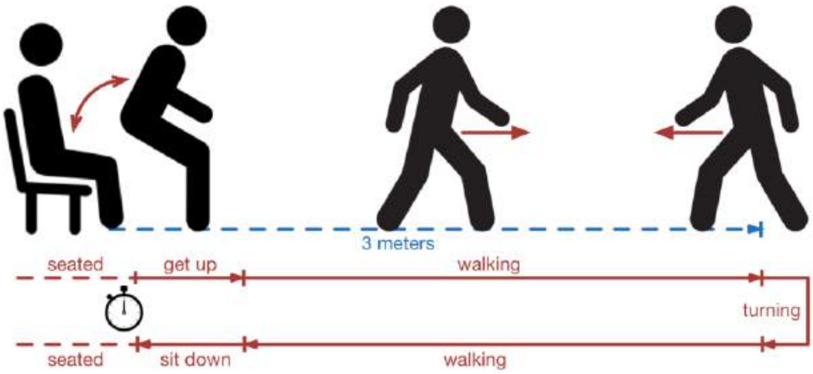

Figure 7: Timed Up and Go (TUG) test execution

A complete execution of a TUG test is characterised by specific phases and transitions:

- a *sitting phase*, when the patient is seated before and after walking from and to the chair;
- a *seated-standing transition*, when the patient stands up from the chair;
- a *walking phase*, when the patient walks from and to the chair;
- a *turning phase*, when the patient turns after the initial 3 meters walk;
- a *standing-seated transition*, when the patient sits back down in the chair after the walk.

The ability of the robot to monitor and measure patient performance during a TUG test is strictly related to the ability of automatically identifying the phases and transitions defined before. The identification on these phases and transitions allows measuring the following performance parameters and mobility indicators:

- the duration of the *seated-standing transition*, i.e., the time the patient takes to stand up from the chair, as an indicator of the smoothness of getting up;
- the time required to the patient to start walking after getting up, to identify gaps as indicators of balance and stabilisation issues;
- the duration of the *walking phase* and the gait speed;
- the duration of the *turning phase*, as a long turning time is an indicator of abnormal physical mobility;
- the duration of the *standing-seated transition*, i.e., the time the patient takes to sit back down in the chair, as an indicator of the smoothness of sitting down;
- the overall execution time to score patient's mobility skills.

An overview of gait analysis and mobility evaluation methods was provided in Deliverable 4.1 [13]. Different approaches have been investigated to automate the execution of TUG tests, and an overview of the proposed methods and technologies used for TUG instrumentation is provided in [16]. Several approaches rely on the availability of wearable sensors and other ambient sensors to be positioned in the environment. However, despite their small size, wearable sensors have to be properly positioned and oriented on the patient, and may be uncomfortable or interfere with his/her natural movement. While ambient sensors are not required to be worn and enable a continuous monitoring of the patient, the assessment can only take place in the environment they are mounted in.

Inspired by the solutions presented in [17] and [18], the proposed approach aims at identifying the different phases and transitions in patient's movement by applying motion tracking and analysis techniques that rely on the skeleton identification and tracking capabilities of the Microsoft Kinect device available on the MARIO robot. The Kinect is able to detect and track the position (in a three-dimensional coordinate space) of 20 joints of the human body skeleton, as shown on the left in Figure 8. When the Kinect is switched on and a person is in the range of the device, the robotic framework available on the Kompai robot provides a streams of timestamped data elements with the positions (in terms of x, y and z coordinates) of the tracked joints. In order to identify the different phases and transitions in the execution of a TUG test, the Motion Tracker component focuses on patient’s torso, by tracking over time the positions of the *Spine Shoulder* and *Spine Base* joints. The location of these joints for a seated and standing person are shown in the images in Figure 8.

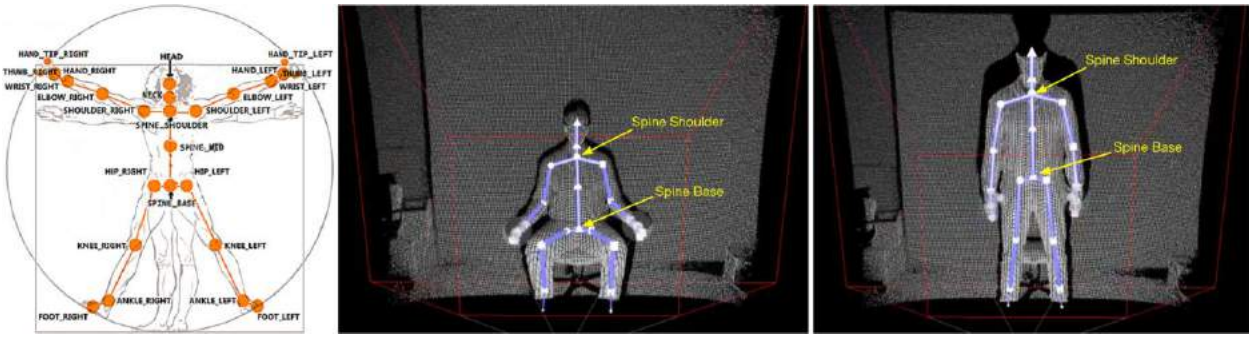

Figure 8: Kinect skeleton joints and position of the *Spine Shoulder* and *Spine Base* joints in a seated and standing person

To monitor the execution of a TUG test, MARIO will exploit its ability to locate and approach the user (as part of the behavioural abilities investigated in Work Package 6), so as to position itself in front of a seated patient at a distance grater that 3 meters. The patient will then be instructed to perform the required movements (get up - walk - turn - walk back - sit down) and the position of the reference joints are tracked over time. By analysing how the position of the *Spine Shoulder* and *Spine Base* joints change along the reference coordinate space (as illustrated in Figure 9), specific patterns corresponding to the different phases and transitions can be identified.

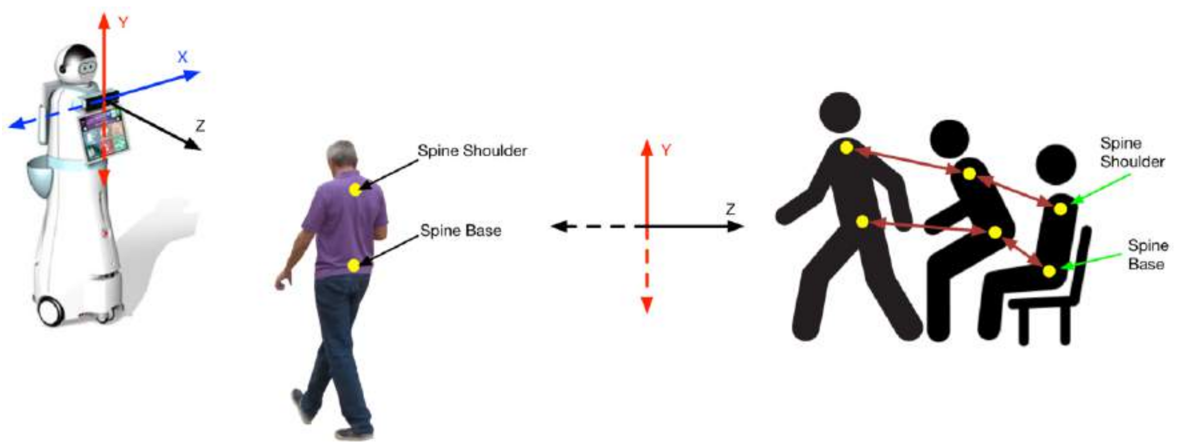

Figure 9: Reference coordinates space and joints tracking

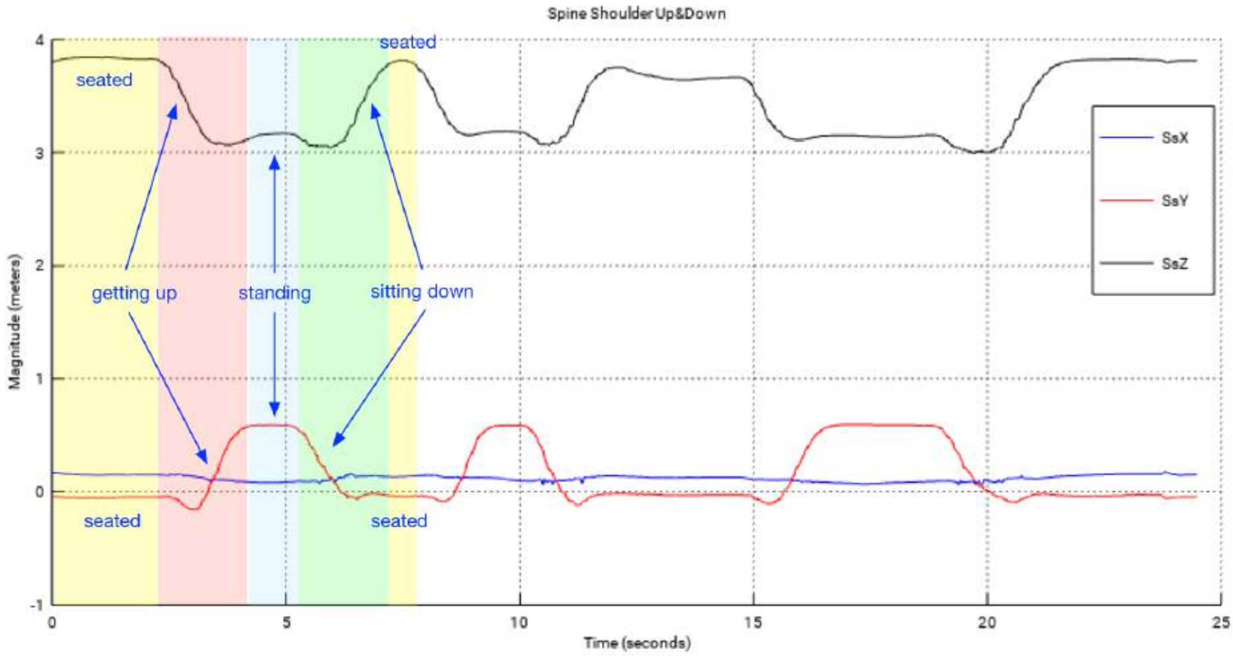

Figure 10: *Spine Shoulder* joint tracking when getting up and sitting down

Figure 10 shows how the position of the *Spine Shoulder* joint changes over time along the three dimensions, as tracked in an experimental setting where the user is asked to get up and sit back down from a chair for three times. Relevant phases, corresponding to a seated and standing position, and related transitions, corresponding to the user getting up and sitting down, are clearly distinguishable, considering in particular the observed variations of the joint position along the Y and Z dimensions. Specifically, while the user gets up from the chair the joint position increases along the Y dimension and decreases along the Z dimension. A complementary pattern can be observed while the user moves to sit back down in the chair, as the joint's position decreases along the Y dimension and increases along the Z dimension. Similar patterns can be observed for the *Spine Base* joint.

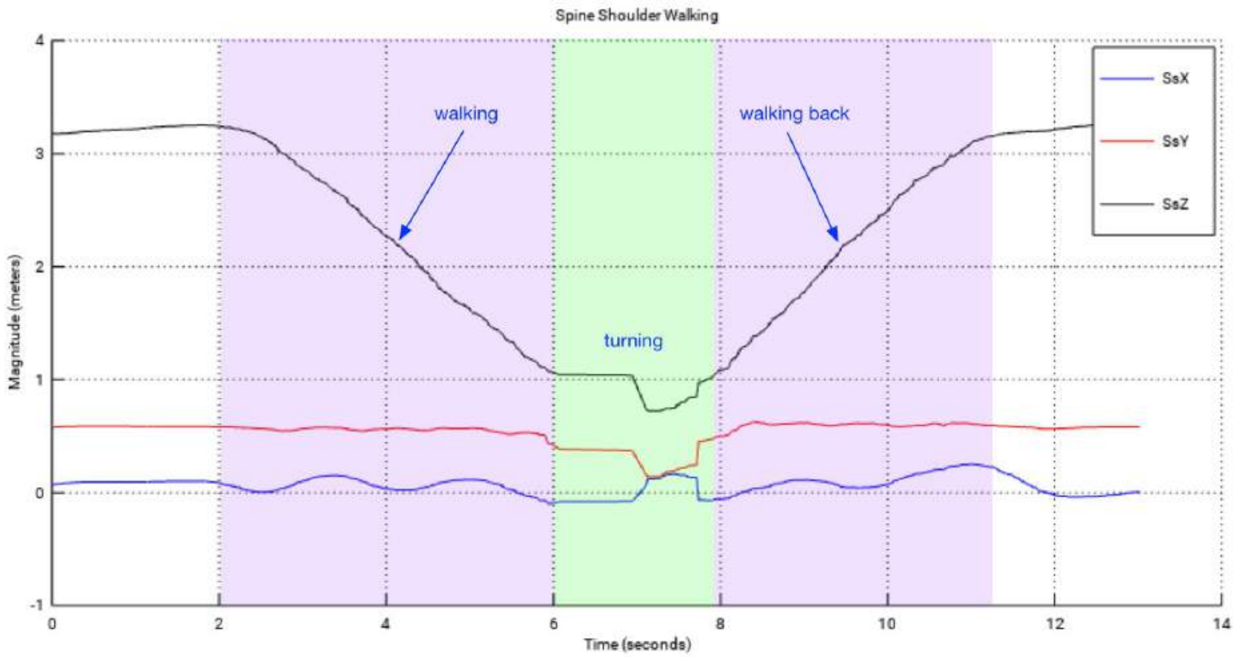

Figure 11: ***Spine Shoulder*** **joint tracking when walking and turning**

Figure 11 shows the evolution over time of the *Spine Shoulder* joint position when the user is asked to walk for three meters towards the robot, turn and walk back to the chair. The walking phases and the turning phase can be identified by considering joint's position along the Z dimension. When the user walks towards the robot the joint's position gradually decreases (as the user moves closer to the Kinect), while it gradually increases when the user walks back to the chair. This also directly allows calculating the average gait speed, by simply considering the walked distance over time. The minimum observable in the joint's position along the Z dimension and the surrounding region correspond to the turning phase. The irregularities observable during the turning phase are due to the fact that the Kinect may be temporarily unable to recognise and track the body skeleton while the user is turning. A similar pattern can be observed for the *Spine Base* joint.

4.3. Security and Privacy

As performing a CGA involves producing and accessing personal and health data about the patient, MARIO must be able to identify the specific user, to ensure that the interaction takes place with the intended patient, as well as the care staff members who can access the personal and health data and add new personal information for the patient. Patient and user identification is a common requirement for the MARIO framework. While initial trial activities will take place under the guidance and supervision of the care staff, user identification will rely on RFID tags and the ability to detect them using the RFID antenna mounted on the robot, as investigated in Work Package 6. This builds on the assumption that RFID tags are worn by the users (including both the caregiver(s) and the patient) and tag identifier are associated with authorized user identities and roles, to identify them within the environment. The identification process aims at ensuring that test executions and CGA question responses and observations are only initiated and considered valid if the user has an RFID tag that has been detected at the time of questioning.

As already mentioned in Section 4.2.1, standard account-based authentication mechanisms and encrypted connections are used to secure the access to patient-related data, in particular when external devices are used by the caregivers to access the CGA application. Additional role-based access control (RBAC) mechanisms can be put in place to grant access to different types of data depending on the role associated with the members of the care staff. For example, the main reference caregiver can be granted access to the full set of recorded responses to the different questions, while other members of the care staff can only get access to the corresponding score.

To prevent patient's identity from being connected with collected information, basic data anonymization principles will be applied, with a focus on the de-identification process of removing/masking personal identifiers (such as patient's name) and introducing anonymous identification codes such as the patient ID mentioned in Section 4.2.1, which can be re-linked to the full patient profile only by trusted, authorized parties such as the main reference caregiver of the patient. It is worth mentioning that some of the items in the assessment questionnaires (in particular in the SPMSQ) are based on so-called quasi-identifiers[8], such as patient's birth date or age, home address and his/her mother's maiden name. While having access to this information is required in order to check patient's answers and allow the reference caregiver to validate the score automatically assigned by the software, access to this data can be restricted depending on user's role, as mentioned before. Similarly, if there is the need to record video fragments during observation-based test executions for later analyses, the Kinect device can be configured to capture videos where only the depth view and/or skeleton view are recorded (as in Figure 8) that prevent the user from being identified or recognized.

Data stored in the knowledge base are secured by relying on the security tools provided by the underlying Virtuoso triplestore[9], which features built-in data access and security mechanisms[10], ranging from authentication, access control lists and Transport Layer Security (TLS) for Open/Java Database Connectivity (ODJC/JDBC) access, to standard role-based security for the internal database, for the SPARQL Protocol and RDF Query Language (SPARQL) and for Resource Description Framework (RDF) Graphs.

4.4. Development Status, Validation and Long-term Evolution

The software implementing the questionnaire-based test execution process is available in the MARIO SVN repository under the path `trunk/cnr/ludwig/src/applications/cga`. The application, written in the Python programming language, is fully integrated with the other components of the MARIO software framework and is able to undertake a dialogue-based interaction on the basis of test questionnaire scripts. In particular, 69 questions were formulated in both English and Italian and their conditional execution order was defined. These questions cover the items of 6 out of the 8 tests of a CGA, namely the Co-Habitation Status, Medication Use, Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL), Short Portable Mental Status Questionnaire (SPMSQ) and Mini Nutritional Assessment (MNA) tools. The data

[8] http://stats.oecd.org/glossary/detail.asp?ID=6961

[9] http://virtuoso.openlinksw.com/

[10] https://virtuoso.openlinksw.com/virt_faq/ - Data-access and Security

related to the items in the Exton-Smith Scale (ESS) and Cumulative Illness Rating Scale (CIRS) are not explicitly intended to be provided by the patient and will be considered as part of the information input by the caregivers. The application is able to automatically assign clinical scores to the different items and calculate the corresponding assessment scores according to the rating scales defined for each assessment tool.

The observation-based test execution capabilities that exploit the Kinect device are being developed in the C++ programming language and are being tested in experimental settings in conjunction with Work Package 6 ongoing activities. The results presented in this document confirm the feasibility of the approach, in particular under test execution conditions where the robot is positioned in front of the user and the execution boundaries are well defined (as it is the case when the test is performed by a patient instructed by the caregiver). The impact of different mutual orientations and positions of the user with respect to the Kinect are being considered, as the ability to clearly identify and distinguish the movement patterns varies depending on the mutual distance and position.

The capabilities and potential benefits of the CGA module have to be validated from the perspective of both the patients and the formal caregivers. Validation activities and procedures that aim at evaluating the effectiveness of the CGA module are detailed in Deliverable 8.1 [10]. In particular, trial activities that will be carried out in the IRCCS pilot site focus on validating the effectiveness of the MARIO platform equipped with the CGA module. The evaluation procedures aim to:

- test and validate whether a CGA can be effectively carried out by the MARIO robot, with results that are *qualitatively* comparable with those recorded when the assessment is performed by formal caregivers;
- test and validate whether there is potential for caregivers and physicians to gain benefit when delegating MARIO to perform the CGA (or part of it) on their behalf, e.g., because of a reduction of the burden for the health professionals.

The intermediate results of testing and validation activities coming from the scheduled trials will drive the additional design and development stages of the CGA module. The application is expected to evolve in order to increase the multidimensional and multidisciplinary assessment capabilities. This will mainly include the introduction of so-called *sentiment analysis* capabilities (investigated in Work Package 5), with the aim of assessing emotional aspects and patient's mood, as well as the definition of a continuous multidimensional monitoring approach, where physical parameters (such as vital signs acquired through monitoring sensors) are combined with and contribute to the overall patient assessment and MPI calculation. In the long term, the robot will autonomously identify suitable contextual scenarios for initiating the CGA, so that patient's status can be assessed on a regular basis, increasing the frequency of the assessment with the execution of some tests on a daily, weekly or monthly basis.

While the CGA module currently focuses on the calculation of the MPI according to its original formulation [5], the extension proposed in Deliverable 4.2 [19] will be considered, by enriching the model with elements resulting from human-robot interaction and the possibility of obtaining additional parameters from wearable sensors connected to MARIO. In particular, the extended MPI model takes into account additional indicators related to the heart rate, respiratory rate and blood pressure of the patient, as well as indicators derived from monitoring patient’s performance while using other applications (such as playing games) available on the robot.

Similarly, additional techniques are being investigated in conjunction with the activities of Work Package 6 in order to enable the robot to continuously measure and monitor mobility indicators related to gait and balance assessment. The patient is usually required to perform specific movements in a TUG test for measuring performance indicators. However, the ability to identify patterns indicating that the patient is sitting or standing, getting up or down, and moving, can allow measuring relevant indicators by tracking patient’s behaviour in his/her daily activities, without the need of explicitly performing a TUG test session.

5. Conclusions

In this Deliverable the design and development of the MARIO robotic module for supporting the Comprehensive Geriatric Assessment (CGA) and calculating a Multidimensional Prognostic Index (MPI) was presented. The approaches, methods, tools and software components that have been described are the main results of the activities carried out in Task 4.3. They directly contribute to the achievement of the objective of developing a CGA module for the robotic platform, through a multidisciplinary interaction based on a user-centered design approach.

The software module for CGA and MPI is part of the MARIO applications that will be deployed and validated during the trials that will take place in the Italian (IRCCS) and Irish (NUIG) pilot sites. It will thus be tested and validated with patients in hospital settings and in nursing facility settings. The outcome and continuous feedback provided by trial activities will further contribute to the refinement and evolution of CGA module towards the final validation phase.

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Annex 1 – CGA and MPI Assessment Tools

This Annex includes the eight assessment tools that are used by health professionals in order to carry out a CGA and calculate the MPI for a patient. The different assessment tools are summarized in the following (including the time that is typically required to execute the test by a caregiver) and then detailed, by reporting the items that compose each test and the corresponding scores that contribute to the MPI.

Co-habitation Status

Focus: social aspects related to household composition, home services and institutionalization.

Brief description: it is composed of a single item that records the co-habitation status of the patient, i.e., whether he/she lives alone, with his/her relatives or is assisted by a nurse, or is hosted in a health care facility.

Required execution time: less than one minute.

Medication Use

Focus: polypharmacotherapy and current drugs assumption.

Brief description: defined according to the Anatomical Therapeutics Chemical Classification code system, it is composed of a single item that records the number of drugs used by the patient.

Required execution time: less than one minute.

Activities of Daily Living (ADL)

Focus: functional status and abilities.

Brief description: it is composed of six items that are used to assess patient's functional abilities in performing basic activities of everyday life: bathing, dressing, toileting, continence, transferring and feeding. The overall score ranges from 6 (autonomous patient, lives independently) to 0 (patient fully dependent on external assistance).

Required execution time: between 5 and 10 minutes.

Instrumental Activities of Daily Living (IADL)

Focus: functional status and abilities.

Brief description: it is composed of eight items that are used to assess patient's functional abilities in performing additional activities of everyday life: ability to use the phone, shopping, food preparation, housekeeping, laundry, mode of transportation, responsibility for own medications, and ability to handle finances. The overall score ranges from 8 (autonomous patient, lives independently) to 0 (patient fully dependent on external assistance).

Required execution time: between 5 and 10 minutes.

Short Portable Mental Status Questionnaire (SPMSQ)

Focus: cognitive status.

Brief description: it is composed of ten items and the patient is asked to answer questions that aim at assessing his/her orientation in time and place, short and long term memory, and basic calculation abilities. The overall score is given by the number of wrong answers and thus ranges from 0 to 10.

Required execution time: between 5 and 10 minutes.

Exton-Smith Scale (ESS)

Focus: pressure sores risk.

Brief description: it is composed of five items used to evaluate the physical and mental conditions, the activity level, the incontinence degree and mobility in bed, each assessed on a scale from 1 to 4. The overall score ranges from 5 to 20 and allows estimating the risk of developing pressure sores, with a low score corresponding to a high risk.

Required execution time: less than 3 minutes.

Cumulative Illness Rating Scale (CIRS)

Focus: co-morbidities assessment.

Brief description: it is composed of fourteen items and is used to assess co-morbidities by assigning a co-morbidity score to each major area related to patient’s health (heart, vascular, hematopoietic, etc.), on a scale from 1 (none) to 5 (extremely severe). The assigned scores allow calculating an Illness Severity Score (CIRS-IS) and a Comorbidity Index (CIRS-CI).

Required execution time: up to 20 minutes.

Mini Nutritional Assessment (MNA)

Focus: nutritional status.

Brief description: it is composed of eighteen items, grouped into four assessment areas (anthropometric, general, dietary and self assessment), and is used for estimating a Malnutrition Indicator Score. The score allows evaluating whether the patient is well-nourished, at risk of malnutrition or malnourished.

Required execution time: between 5 and 10 minutes.

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MULTIDIMENSIONAL PROGNOSTIC INDEX (MPI) *

CO-HABITATION STATUS

Does the patient live:	
Alone	
With relatives/nourse	
In institution	

MEDICATION USE

Number of drugs used	

** Pilotto A, Ferrucci L, Franceschi M et al. Development and validation of a Multidimensional Prognostic Index for 1-Year Mortality from a Comprehensive Geriatric Assessment in Hospitalized Older Patients. Rejuvenation Res 2007*

ACTIVITIES OF DAILY LIVING (ADL) *

A) **BATHING** (either sponge bath, tub bath, or shower)	
- Receives no assistance (gets in and out of tub by self if tub is usual means of bathing)	1
- Receives assistance in bathing only one part of the body (such as back or a leg)	1
- Receives assistance in bathing more than one part of the body (or not bathed)	0
B) **DRESSING** (gets clothes from closets and drawers – including underclothes, outer garments, and using fasteners including braces, if worn)	
- Gets clothes and gets completely dressed without assistance	1
- Gets clothes and gets dressed without assistance except for assistance in tying shoes	1
- Receives assistance in getting clothes or in getting dressed, or stays partly or completely undressed	0
C) **TOILETING** (going to the "toilet room" for bowel and urine elimination, cleaning self after elimination, and arranging clothes)	
- Goes to "toilet room," cleans self, and arranges clothes without assistance (may use object for support such as cane, walker, or wheelchair and may manage night bedpan or commode, emptying same in morning)	1
- Receives assistance in going to "toilet room" or in cleaning self or in arranging clothes after elimination or in use of night bedpan or commode	0
- Doesn't go to room termed "toilet" for the elimination process	0
D) **TRANSFER**	
- Moves in and out of bed as well as in and out of chair without assistance (may be using object for support such as cane or walker)	1
- Moves in and out of bed or chair with assistance	0
- Doesn't get out of bed	0
E) **CONTINENCE**	
- Controls urination and bowel movement completely by self	1
- Has occasional "accidents"	0
- Supervision helps keep urine or bowel control, catheter is used, or is incontinent	0
F) **FEEDING**	
- Feeds self without assistance	1
- Feeds self except for getting assistance in cutting meat or buttering bread	1
- Receives assistance in feeding or is fed partly or completely by using tubes or intravenous fluids	0

TOTAL _________

** Katz S, Ford AB, Moskowitz RW et al. Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychological function. JAMA 1963; 185: 914-19.*

INSTRUMENTAL ACTIVITIES OF DAILY LIVING SCALE (IADL)*

A) **ABILITY TO USE TELEPHONE**	
- Operates telephone on own initiative: looks up and dials numbers, etc.	1
- Dials a few well-known numbers	1
- Answers telephone but does not dial	1
- Does not use telephone at all	0
B) **SHOPPING**	
- Takes care of all shopping needs independently	1
- Shops independently for small purchases	0
- Needs to be accompanied on any shopping trip	0
- Completely unable to shop	0
C) **FOOD PREPARATION**	
- Plans, prepares and serves adequate meals independently	1
- Prepares adequate meals if supplied with ingredients	0
- Heats, serves and prepares meals or prepares meals but does not maintain adequate diet	0
- Needs to have meals prepared and served	0
D) **HOUSEKEEPING**	
- Maintains house alone or with occasional assistance (e.g. “heavy work domestic help”)	1
- Performs light daily tasks such as dishwashing, bed making, etc.	1
- Performs light daily tasks but cannot maintain acceptable level of cleanliness	1
- Needs help with all home maintenance tasks	0
- Does not participate in any housekeeping tasks	0
E) **LAUNDRY**	
- Does personal laundry completely	1
- Launders small items; rinses stockings, etc.	1
- All laundry must be done by others	0
F) **MODE OF TRANSPORTATION**	
- Travels independently on public transportation or drives own car	1
- Arranges own travel via taxi, but does not otherwise use public transportation	1
- Travels on public transportation when accompanied by another	1
- Travel limited to taxi or automobile with assistance of another	0
- Does not travel at all	0
G) **RESPOSIBILITY FOR OWN MEDICTIONS**	
- Is responsible for taking medication in correct dosages at correct time	1
- Takes responsibility if medication is prepared in advance in separate dosage	0
- Is not capable of dispensing own medication	0
H) **ABILITY TO HANDLE FINANCES**	
- Manages financial matters independently (budgets, writes checks, pays rent, bills goes to bank), collects and keeps track of income	1
- Manages day-to-day purchases, but needs help with banking, major purchases, etc.	1
- Incapable if handling money	0

TOTAL _________

* *Lawton MP, Brody EM. Assessment of older people:self-maintaining and instrumental activities of daily living. Gerontologist 1969;9:179-86.*

SHORT PORTABLE MENTAL STATUS QUESTIONNAIRE (SPMSQ) *

(Record the errors)

What is the date today? (Correct only when the month, date, and year are all correct)	1
What day of the week is it?	1
What is the name of this place? (Correct if any of the description of the location is given)	1
What is your street address?	1
How old are you?	1
When were you born?	1
Who is the president (or the Pope) now? (Requires only the correct last name)	1
Who was president (or the Pope) just before him?	1
What was your mother's maiden name?	1
Subtract 3 from 20 and keep subtracting 3 from each new number at least for 3 times (The entire series must be performed correctly to be scored as correct)	1

TOTAL _________

** Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. J Am Geriatr Soc. 1975; 23:433-441.*

EXTON-SMITH SCALE (ESS) *

(evaluation of pressure sores risk)

General Condition		**Incontinence**	
Bad	1	Doubly incontinent	1
Poor	2	Usually of urine	2
Fair	3	Occasional	3
Good	4	Not	4
Mental State		**Mobility in Bed**	
Stuporosous	1	Immobile	1
Confused	2	Very limited	2
Apathetic	3	Slightly limited	3
Alert	4	Full	4
Activity		**TOTAL _________**	
In bed all day	1		
Chairfast	2	*Score 16-20: minimum risk*	
Walks with help	3	*Score 10-15: medium risk*	
Ambulant	4	*Score 5-9: high risk*	

** Bliss MR., McLaren R., Exton-Smith AN. Mattresses for preventing pressure sores in geriatric patients. Mon Bull Minist Health Public Health Lab Serv 1966*

CUMULATIVE ILLNESS RATING SCALE (C.I.R.S.) *

	NONE	MILD	MODERATE	SEVERE	EXTREMELY SEVERE
1. Cardiac (heart only)	1	2	3	4	5
2. Hypertension (rating is based on severity)	1	2	3	4	5
3. Vascular (arteries, veins, lymphatics)	1	2	3	4	5
4. Respiratory (lungs, bronchi, trachea)	1	2	3	4	5
5. EENT (eye, ear, nose, throat, larynx)	1	2	3	4	5
6. Upper GI (esophagus, stomach, duodenum, biliary and pancreatic trees)	1	2	3	4	5
7. Lower GI (intestines, hernias)	1	2	3	4	5
8. Hepatic (liver only)	1	2	3	4	5
9. Renal (kidneys only)	1	2	3	4	5
10. Other GU (ureters, bladder, urethra, prostate, genitals)	1	2	3	4	5
11. Musculo-skeletal-integumentary (muscles, bone, skin)	1	2	3	4	5
12. Neurological (brain, spinal cord, nerves)	1	2	3	4	5
13. Endocrine-metabolic (including diabetes, hyperlipidemia, infections, toxicity)	1	2	3	4	5
14. Psychiatric (dementia, depression, anxiety, agitation, psychosis)	1	2	3	4	5

ILLNESS SEVERITY SCORE (CIRS-IS) mean of all single item (excluded the psychiatric item)	**COMORBIDITY INDEX (CIRS-CI)** number of items with a score of 3 or greater (excluded the psychiatric item)
______________________________	______________________________

** Conwell Y, Forbes NT, Cox C, Caine ED. Validation of a measure of physical illness burden at autopsy: the Cumulative Illness Rating Scale. J Am Geriatr Soc 1993; 41: 38-41.*

MINI NUTRITIONAL ASSESSMENT (MNA) *

A) Anthropometric Assessment

1) Body Mass Index (BMI) Weight:________________kg Height:________________cm	0 BMI <19	1 BMI = 19-20	2 BMI = 21-22	3 BMI ≥ 23
2) Mid-arm circumference (MAC) in cm___________	0 MAC<21	0.5 MAC ≤ 22	1 MAC > 22	
3) Calf circumference (CC) in cm_____________	0 CC < 31	1 CC ≥ 31		
4) Weight loss (last three months)	0 loss > 3Kg	1 does not know	2 loss between 1-3Kg	3 no weight loss

B) General Assessment

5) Lives independently (not in a nursing home or hospital)	0 no	1 yes
6) Takes more than 3 prescription drugs per day	0 yes	1 no
7) Has suffered psychological stress or acute disease in the past 3 months	0 yes	2 no

8) Mobility	0 bed or chair bound	1 able to get out of bed/chair but does not go out	2 goes out
9) Neuropsychological problems	0 severe dementia or depression	1 mild dementia	2 no psychological problems

10) Pressure sores or skin ulcers	0 yes	1 no

C) Dietary Assessment

11) How many full meals does the patient eat daily?	0 1 meal	1 2 meals	2 3 meals
12) Consumes: Points if: 1 yes 0 2 yes 0.5 3 yes 1	at least 1 serving of dairy products (milk, cheese, yogurt) per day yes no	2 or more servings of legumes or eggs per week yes no	meat, fisk or poultry every day yes no

13) Consumes 2 or more servings of fruits or vegetables per day?	0 no	1 yes

14) Has food intake declined over the past 3 months due to loss of appetite?	0 severe loss of appetite	1 moderate loss of appetite	2 no loss of appetite
15) How much fluidi s consumed per day?	0 less than 5 glasses	0.5 5 to 9 glasses	1 more than 9 glasses
16) Mode of feeding	0 with assistance	1 self-feed with some difficulty	2 self-feed without any problem

D) Self Assessment

17) Do they view themselves a s having nutritional problems?	0 major malnutrition	1 does not know	2 no nutritional problems

18) In comparison with other people of same age, how they consider their health status?	0 not as good	0.5 does not know	1 as good	2 better
			TOTALE (max 30 punti)_____________	

MALNUTRITION INDICATOR SCORE: ≥ 24 = well-nourished, 17-23.5 = at risk of malnutrition, < 17 = malnourished

* *Vellas B et al. The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients. Nutrition 1999; 15: 116-22.*