ALMI

Case study title: ALMI **(**Ambient Assisted Living for Long-term Monitoring and Interaction)

Description

With a rapidly ageing population, the world is facing a social care crisis (Appleby, 2009). Without a step change in the provision of social care, especially to the elderly, the increase in the budgets and resources allocated to social care will soon become unsustainable. *Ambient assisted living* (Blackman et al., 2016) (i.e., assisted living support provided in a person's daily environment, with the aid of robotic and autonomous systems – RAS, Artificial Intelligence – AI, and other technologies) is widely envisaged as a key component of such a step change (Lee et al., 2018).

Given this vision, the development of assisted-living RAS and AI solutions has been the focus of intense research and industrial effort in recent years. Designed to help or even replace carers at home and in care homes, these solutions aim to support people with motor or cognitive impairments in a wide range of tasks, increasing their ability to pursue daily living activities independently. These advances have provided RAS solutions capable of assisting elderly and disabled users both in a monitoring/advisory role and with physical tasks. However, integrating the two types of assistance into a *combined assistive-care RAS solution that can be used safely over a long period of time* still poses significant challenges (SPARK, 2015).

In the ALMI project, we employ a TIAGo robot that uses both its speech interaction and its object manipulation capabilities to help a user with mild motor and cognitive impairments in the daily activity of preparing a meal. Specifically, the TIAGo robot (i) provides step-by-step voice instructions guiding the user through the meal preparation task; (ii) fetches and hands to the user some of the food ingredients, kitchen utensils, crockery, etc. required for these steps; (iii) reminds the user (if needed) where to find other items that are required for the task, and that the robot cannot reach or handle. Providing such support requires the robot to dynamically create, update and exploit a "knowledge store" of household item locations (over a long period of time); to track the user's progress with the meal preparation task, so that instructions are delivered progressively and repeated if necessary; to handle disruptions safely, etc.

The safe handling of disruptions requires the robot to react to events such as task interruptions due to a phone call received by the user, or loss of vision due to the light being switched off accidentally by the user, or as a result of a power cut. If such unexpected events interrupt the execution of the task, the robot will mitigate the detrimental effects of interruption (if there are remedial actions that can be performed), or issue an alert when an unsafe situation cannot be handled directly by using its capabilities.

TIAGo is a highly customisable mobile robotic platform with 15 degrees of freedom (DoF). The TIAGo robot comprises a mobile base with a footprint of 54cm, an adjustable height torso enabling the robot to vary its overall height between 110–140cm, a pan-tilt head, and a 7 DoF manipulator arm with a reach of 87cm and a payload of 3kg. The mobile base is provided with a differential drive capable of speeds of up to 1 m/s, and uses a LIDAR laser for indoor navigation. The TIAGo control software and applications are deployed on an Intel i7 (7th

generation) computer with 16 GB of RAM, 500 GB of disk space, and running Ubuntu LTS 64-bit with the RT Preempt real-time framework. Multiple ROS LTS controllers running in a real-time control loop are used to manage robot components including its torso, head and arm positions, with joint trajectory controllers used from groups of joints and a Head Action Server for controlling the robot's gaze. The TIAGo navigation unit supports laser-based mapping and self-location, with obstacle avoidance and navigation to map point capabilities. The upper-body motion engine controllers support path planning with self-collision avoidance, and come with a wide range of pre-programmed motions and facilities for defining customised motions. Particularly relevant for ALMI, TIAGo supports (i) speech-based interaction with the users through its integrated ACAPELA[1] text to-speech system and DeepSpeech[2] speech-to-text module; (ii) object and people detection thanks to its ASUS XTION Pro Live 3D Camera mounted on the robot's head.

Appleby, J. Spending on health and social care over the next 50 years. Why think long term?, 2013. The King's Fund. **4.** M. W. Bewernitz, W. C. Mann, P. Dasler, and P. Belchior. Feasibility of machine-based prompting to assist persons with dementia. *Assistive Technology*, 21(4):196–207, 2009.

Blackman, S., Matlo, C., Bobrovitskiy, C., Waldoch, A., Fang, M L., Jackson, P., Mihailidis, A., Nygard, L., Astell, A., and Sixsmith, A. Ambient assisted living technologies for aging well: a scoping review. *Journal of Intelligent Systems*, 25(1):55–69, 2016

Lee H R. and Riek L D. Reframing assistive robots to promote successful aging. *ACM Transactions on Human-Robot Interaction (THRI)*, 7(1):1–23, 2018.

SPARC – The Partnership for Robotics in Europe. Robotics 2020 multi-annual roadmap for robotics in Europe, 2015.

Stage of Development (Technical contributor)

Deployed, SIMULATION, MODELLING

Expert info

Expertise of the stakeholders involved in devising the SLEEC rules

Number of stakeholders writing the rules

Stakeholder names	Expertise
TS-1	Computer Science
N-TS-1	Social/Moral Psychology
N-TS-2	Moral Psychology, Law
TS-2	Engineer/Goal Modelling

Main functionality and purpose

[1] www.acapela-group.com

[2] https://github.com/mozilla/DeepSpeech

In the ALMI project, we harness the PAL Robotics framework, TIAGo, and evolve it into an array of social robotic solutions. TIAGo employs both its voice interaction for audio commands and its object manipulation skills to assist a user with mild motor and cognitive impairments in the everyday task of meal preparation. Moreover, TIAGo is equipped with the essential manipulation capabilities and assurance evidence for the customized robotic arm, and it also possesses environment monitoring capabilities to establish and maintain a knowledgebase of objects.

Whenever disruptive changes occur (for example, when the user abandons a task), TIAGo adapts both its configuration and behaviour to achieve task completion, or to gracefully degrade, preserving safety even if the task is not successfully completed. To achieve this, we developed methods for the synthesis of adaptation plans for the robotic platform. Determining the course for adaptation in our experimental environment entails securing a safe combination of robot configuration and task plan specification for the robot's execution context.

PAL Robotics constructed the first prototype of a novel robotic arm featuring new sensors and capabilities to adhere to the standards of industrial and personal care robotics. Cutting-edge electronics and actuators have been applied that allowed it to implement more advanced control functions (e.g, force control).Together with the application of brakes, they improved the security features of the TIAGo arm to be able to collaborate closely with humans. The new arm complies with the expected levels of security and robustness. The capabilities of this new arm are tailored for applications involving human-robot interaction. On the one hand, the torque sensing and Ethercat bus allow for superior low-level closed-loop torque control. This allows the full control of the arm in effort mode, which makes the arm compliant. Namely, the control architecture can be modified at a low level by emulating a spring at the joint level, and this permits to use the robot exactly as it was used before, but with this new compliant feature, and not losing any accuracy. All standard robot movements can now be performed safely so that any potential collisions, either with the robot or any external entity, would not harm the human or the robot. On the other hand, there are breaks also at joint level. In the case there was any misuse of the robot, or even the emergency stop was activated, the arm would not fall but maintain position. Hence, as a direct consequence of these two features of the arm, a layer in safety of the interaction between machine and human has been added, without losing any of the previous capabilities of the robot.

TIAGo is also capable of generating a semantic map of an apartment, learning about an object or location, and executing general-purpose tasks as instructed by a user through its human-robot interaction, navigation, and robot-object interaction abilities. The TIAGo knowledge repository consists of a semantic map of the user's surroundings, with the positions of objects specified at particular sites. This semantic map is formulated using the existing ROS (The Robot Operating System) Navigation Stack functionality, after mapping the user's environment and/or inputting the details. The semantic map is devised to be as reusable as possible with custom types of objects with various attributes, thereby enabling TIAGo to hold a variety of household items like furniture, utensils, and meal preparation ingredients. This approach is embodied in a customised middleware that captures and processes information broadcasted to ROS topics,

incorporating it into a knowledge store containing the domain models needed for validation and adaptation.

Normative requirements

1. **Normative requirements in natural language**

   Normative requirements in natural language, in blue the corrected requirements after using N-Tool.

rule id	rule	impact	label(s) (social, legal, ethical, empathetic, or cultural)	stakeholder expertise	authors identifiers
1	When it is time for a meal, inform the user that it is time to cook the meal (breakfast, lunch, or dinner) within x minutes. ● If there is an environmental constraint (e.g., they are busy), remind them later.	-CS -N	cultural	Computer science	TS-1
2	Monitor the time between meals and ensure that the user's last meal does not exceed the max time limit between meals. - If max time limit is exceeded, call caregiver and inform them of the situation and in the meantime, suggest they have a snack.				
3	~~If the human is detected on the floor, call for help (either caregiver or emergency medical help) immediately.~~ ~~● unless the human does not assent with this action~~ If the human is detected on the floor, then ask whether the robot should call for help - When the robot asks whether to call for help and the human does not assent, then do not inform the caregiver or call emergency services.	-P -N -S	Ethical, legal	Computer science	TS-1

4	If a safe path is not identified by the robot to traverse the environment, inform the user about that. ● unless the user is unable to respond (e.g., busy, distressed, etc.)	-N -PH	Empathetic	Computer science	TS-1
5	If user suggests that they want to cook the meal by themselves, allow them to do it. - Estimate the risk of all actions they could do in the kitchen. - If high risk is detected (e.g., shaking while using a knife), suggest that the user stop cooking immediately and safely take over. - Only Interfere if any hazard is detected (e.g., fire)	+A +CS +PH	Social, empathetic	Social/Moral Psychology	N-TS-1
6	Based on user's limitation, give advice on what they should or should not do by themselves (e.g., if user has parkinson's, advice against cutting vegetables and offer to do all the mise en place)	+S +CS +PH	Social, empathetic	Social/Moral Psychology	N-TS-1
7	Before the user manipulates kitchen appliances, check the temperature and warn them as needed (e.g., oven is now hot, be careful when you touch it)	+S	Social, empathetic	Social/Moral Psychology	N-TS-1
8	Monitor the time of the food being prepared and inform the user when they should be ready.	+S	Social, empathetic	Social/Moral Psychology	N-TS-1
9	During first interaction, ask the user about the kinds of cuisines they like, abilities they have, ingredients they typically consume, and food allergies they have. - TIAGo must record, monitor, and keep updated a list of the user's health concerns, dietary restrictions, and allergies.	+SR +CS	Social, empathetic, cultural, Legal	Social/Moral Psychology Law	N-TS-1 N-TS-2
10	When suggesting meals, make sure to consider the cultural, religious, and	+SR +CS	Social, empathetic, cultural	Social/Moral Psychology	N-TS-1

	individual practices of the user.			Law Engineer/Goal Modelling	N-TS-2 TS-2
11	During first interaction, ask the user for an emergency contact. Inform them that this emergency contact will be contacted if they have any emergencies while cooking.	+S +SR	Social, legal	Social/Moral Psychology	N-TS-1
12	Ensure that only the main user (or people authorized by the main user) can see the history of meals cooked. - If data needs to be checked, provide summaries only (e.g., amount of calories and nutrients consumed)	+P	Social, legal	Social/Moral Psychology	N-TS-1
13	If user's motor/cognitive impairment causes them to move in an unpredictable manner (e.g. hands jerking uncontrollably), do not allow agent to hand them sharp, heavy, or otherwise dangerous objects	+B +N +S	Social Legal	Psychology Law	N-TS-2
14	If the user trusts agent to complete tasks it was not designed to do, agent must frequently remind the user of its limitations - Unless user needs particularly special help/attention	+SR +A +T +N	Social Empathetic	Psychology Law	N-TS-2
15	Agent's appearance must be appropriate for its purpose - Unless a particular user needs special design accommodations	+SR +A +PH	Social Empathetic	Psychology Law	N-TS-2
16	Agent's choice of speech and intonation must be calibrated to the demographic background of user	+A +CS	Social Cultural Empathetic	Psychology Law	N-TS-2
17	If agent must provide spoken instructions to user, frame these instructions in first person plural "We". - Independently offer to repeat instructions	+A +CS	Social Cultural Empathetic	Psychology Law Engineer/Goal Modelling	N-TS-2 TS-2

18	Prior to starting cooking, ask the user what their preferred level of detail for the cooking instructions should be.				
19	If user decides to change their mind about a certain cooking approach, recipe, or ingredient, agent must flexibly change course and recalculate a new approach - Unless doing so will cause direct physical harm to the user	+A +S	Social Empathetic	Psychology Law	N-TS-2
20	If user misplaces or changes the location of objects, ingredients, or utensils within the kitchen environment, agent must update its map of kitchen to keep track of new location - Unless new location foreseeably causes physical harm to user, agent must not Interfere with how user wishes to re-organize their kitchen	+A	Social	Psychology Law	N-TS-2
21	~~If smoke detector goes off then call emergency services~~ ~~- Unless the user disables the alarm and it doesn't start again within 5 minutes (so there is no fire, only temporary smoke), then open windows, shut down appliances, ask the user if they are okay, and send an alert to the caregiver.~~ If smoke detector goes off then call emergency services within 2 minutes - Unless the user disables the alarm and the alarm does not restart, then take fire safety measures - Which are to open the windows, ask the user if they are okay, and send an alert to the caregiver	+S +SR	Legal Ethical Empathetic	Engineer/Goal Modelling	TS-2
Concern					

c1	~~When human is on the floor, and the user is occupied and the risk level is high, then the robot must not call emergency services~~
c2	When allowing the user to cook and there is a hazard or high risk level, the agent must not interfere safely
c3	When checking temperature and there is a hazard, the agent must not inform user
c4	When the smoke detector alarm goes off and the user does not disable the alarm, or the alarm restart, then the agent must not call emergency services within 2 minutes
c5	When taking fire safety measures the agent must not open windows
c6	When the user wants to cook the agent must not allow the user to cook
c7	When giving cooking instructions then the agent must not use first person plural language
c8	When the user changes their mind and the risk level is less than high the agent must not recalculate the approach
c9	When giving a suggestion the agent must not consider their cultural or religious practices
c10	When the agent is deployed and an unauthorized person asks for data, then the agent must show data history
c11	When showing data history and the data needs checking, the agent must not provide data summaries
Purpose	
p1	The agent must be able to prepare deployment
p2	The agent must be able to meet user
p3	The agent must be able to inform user
p4	The agent must be able to inform user when the smoke alarm goes off and the user disables the alarm or the alarm restarts
p5	The agent must be able to remind user of its limitations when the user is occupied and the risk level is high
p6	The agent must be able to ask the user if they are well if they are detected on the floor and the human assents to being on the floor
p7	The agent must be able to call emergency services when the human is on the floor and the risk level is high
p8	The agent must be able to ask the user if they are well when the user’s behavior is unpredictable
p9	The agent must be able to show data history to an authorized person

p10	The agent must be able to monitor meal times and inform the user when they are unoccupied
p11	The agent must be able to inform the user when a hazard is detected
p12	The agent must be able to interfere safely when a hazard is detected or risk level is high
p13	The user must be able to change their mind when the risk level is less than high
p14	The agent must be able call emergency services when a human is on the floor
p15	The agent must be able to call emergency services when the smoke detector alarm goes off
Impact keys: A = autonomy, PH = psychological health (non-maleficence), P = privacy, E = explainability, T = transparency, CS = cultural sensitivity, SR = social requirement, B 'beneficence' (doing good), N 'non-maleficence' (preventing/avoiding harm), and S 'safety'. ''+" and "-" for positive and negative impacts respectively.	

Moving specifically for the task in different location
Monitor the environment

2. **Rules in the SLEEC DSL**
   The stakeholders corrections after analyzing the well-formedness of the rules using our N-Tool are commented and in blue.

```
def_start

    // Events
    event PreparingDeployment
    event AgentDeployed
    // Communicating with people
    //***  Added to resolve s-conflict
    // ** Uncomment the event below
    // event AskCallHelp
    //*****************************
    event MeetingUser
    event InformUser
    event InformCaregiver
    event CallEmergencyServices
    event RemindLater
    event AgentHasAppropriateAppearance
    event AskForDetailLevelOfInstructions
    event UseFirstPersonPluralLanguage
    event CalibrateSpeech
    event RemindUserOfLimitations
    // Safety
     event AskForEmergencyContact
    event HumanOnFloor
    event SmokeDetectorAlarm
    event OpenWindows
    event FireSafetyMeasures
```

```
        event AskUserIfOK
        event InterfereSafely
        event UserHasLimitation
        event CheckTemperature
        event FoodPreparation
        event TrackTime
       event UserUnpredictable
        event GiveUserDangerousObjects
        // Cooking/kitchen related specifically
        event MonitorMealTime
        event BeforeCookingBegins
        event UserWantsToCook
       event AllowUserToCook
       event GiveSuggestion
       event GivingCookingInstructions
       event ConsiderUserPractices
       event UserChangeItemLocation
       event UserChangeMind
        event RecalculateApproach
       // Privacy
       event ProvideDataSummaries
       event CollectandRecordInformation
       event UpdateInformation
       event ShowDataHistory
       event UpdateMap

          // measures
          measure userOccupied: boolean
          measure timeBetweenMeals: numeric
          measure personAuthorized: boolean
          measure dataNeedsChecking: boolean
          measure userAsksForAppropriateTasks: boolean
          measure userNeedsSpecialAccomodations: boolean
          measure userDisablesAlarm: boolean
          measure alarmRestarts: boolean
          measure needLevel: scale(nlow, nmedium, nhigh)
          measure humanAssents: boolean
          measure safePathFound: boolean
          measure hazardDetected: boolean
          measure kitchenSafe: boolean
          measure riskLevel: scale(low, medium, high)
          measure alarmOn: boolean

       // constants
       constant maxTimeBetweenMeals = 28800 // is predetermined
def_end

rule_start
R1 when MonitorMealTime then InformUser within 10 minutes
   unless {userOccupied} then RemindLater
// If the max time limit is exceeded, call the caregiver and inform them of the situation and in the meantime, suggest
they have a snack.
R2 when AgentDeployed then TrackTime
R2_1 when TrackTime and ({timeBetweenMeals} > maxTimeBetweenMeals) then InformCaregiver
```

```
R2_2 when TrackTime and ({timeBetweenMeals} > maxTimeBetweenMeals) then GiveSuggestion
R3 when HumanOnFloor then CallEmergencyServices
        unless (not {humanAssents}) then not CallEmergencyServices
// ** Resolving s conflict (comment r3, add 3 rules)
//    3 rules are added, uncomment Rule3b, R3bb,  R3bbb , and comment  R3
// R3b when HumanOnFloor then AskCallHelp
// R3bb when AskCallHelp and (not {humanAssents}) then not CallEmergencyServices
// R3bbb when AskCallHelp and (not {humanAssents}) then not InformCaregiver
// ************************************************
   R4 when InterfereSafely and (not {safePathFound}) then InformUser
        unless {userOccupied}
   R5 when UserWantsToCook then AllowUserToCook
   R5_1 when AllowUserToCook and ({hazardDetected} or ({riskLevel} = high)) then InterfereSafely
   R6 when UserHasLimitation then InformUser
   R7 when UserWantsToCook then CheckTemperature
   R7_1 when CheckTemperature and {hazardDetected} then InformUser
   R8 when FoodPreparation then TrackTime
   R8_1 when TrackTime then InformUser
   R9 when MeetingUser then CollectandRecordInformation
   R9_1 when AgentDeployed then UpdateInformation
   R10 when GiveSuggestion then ConsiderUserPractices
   R11 when MeetingUser then AskForEmergencyContact
   R11_1 when AskForEmergencyContact then InformUser
R12 when AgentDeployed and (not {personAuthorized}) then not ShowDataHistory
R12_1 when ShowDataHistory and {dataNeedsChecking} then ProvideDataSummaries
R13 when UserUnpredictable then not GiveUserDangerousObjects
R14 when AgentDeployed and (not {userAsksForAppropriateTasks}) then RemindUserOfLimitations
        unless ({needLevel} > nmedium)
R15 when PreparingDeployment then AgentHasAppropriateAppearance
        unless {userNeedsSpecialAccomodations}
R16 when PreparingDeployment then CalibrateSpeech
R17 when GivingCookingInstructions then UseFirstPersonPluralLanguage
R17_1 when GivingCookingInstructions then InformUser //offer to repeat
R18 when BeforeCookingBegins then AskForDetailLevelOfInstructions
R19 when UserChangeMind then RecalculateApproach
        unless ({riskLevel} = high)
R20 when UserChangeItemLocation then UpdateMap
        unless ({riskLevel} = high) then InterfereSafely
R21 when SmokeDetectorAlarm then CallEmergencyServices within 5 minutes
        unless ({userDisablesAlarm} and (not {alarmRestarts})) then FireSafetyMeasures
// *** Resolve concern c4 (ADD rules) **********************
//    one rule is added
R21b when SmokeDetectorAlarm then CallEmergencyServices within 2 minutes
unless ({userDisablesAlarm} and (not {alarmRestarts}))
then FireSafetyMeasures
// ************************************************
R21_1 when FireSafetyMeasures then OpenWindows
R21_2 when FireSafetyMeasures then AskUserIfOK
R21_3 when FireSafetyMeasures then InformCaregiver
rule_end

concern_start
// Safety
   c1 when HumanOnFloor and ({userOccupied} and ({riskLevel} = high)) then not CallEmergencyServices
```

```
    // ** Resolve concern c1 : spurious, remove c1
    c2 when AllowUserToCook and ({hazardDetected} or ({riskLevel} = high))  then not  InterfereSafely
    c3 when CheckTemperature and {hazardDetected} then not InformUser

    c4 when SmokeDetectorAlarm and ((not {userDisablesAlarm}) or {alarmRestarts}) then not
CallEmergencyServices within 2 minutes

    c5 when FireSafetyMeasures then not OpenWindows
  // Autonomy
    c6 when UserWantsToCook then not AllowUserToCook
    c7 when GivingCookingInstructions then not UseFirstPersonPluralLanguage
    c8 when UserChangeMind and ({riskLevel} < high) then not RecalculateApproach
// Cultural sensitivity
c9 when GiveSuggestion then not ConsiderUserPractices
// Privacy
c10 when AgentDeployed and (not {personAuthorized}) then ShowDataHistory
// Security
c11 when ShowDataHistory and {dataNeedsChecking} then not ProvideDataSummaries
concern_end

purpose_start
        pr1 exists PreparingDeployment
        pr2 exists MeetingUser
        pr3 exists InformUser
        pr4 when SmokeDetectorAlarm and ({userDisablesAlarm} or {alarmRestarts}) then InformUser
        pr5 exists RemindUserOfLimitations and ({userOccupied} and ({riskLevel} = high))
        pr6 when HumanOnFloor and {humanAssents} then AskUserIfOK
        pr7 when HumanOnFloor and ({riskLevel} = high) then CallEmergencyServices
        pr8 when UserUnpredictable then AskUserIfOK

    // Avoid sharing user's personal information
        p9 exists ShowDataHistory and {personAuthorized}
    // Ensuring that the user gets fed
    p10 exists InformUser and (not {userOccupied}) while MonitorMealTime
    // Must be able to keep the user reasonably safe in the kitchen
        p11 exists InformUser and {hazardDetected}
        p12 exists InterfereSafely and ({hazardDetected} or ({riskLevel} = high))
    // Respecting user's autonomy when they request it
        p13 exists UserChangeMind and ({riskLevel} < high)
    // Must be able to connect user to help when needed
        p14 exists CallEmergencyServices while HumanOnFloor
        p15 exists CallEmergencyServices while SmokeDetectorAlarm
purpose_end
```