Fostering Well-being in Care with the Nautical Designed Plant Watering Robot

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Abstract: The well-being of older people in care homes does not only rely on health and bodily needs but also includes spiritual or social needs. The presence of plants and distraction from everyday routines are two rarely addressed issues in this regard. Having those in mind, we developed the concept of the 'Plant Watering Robot' (PWR), a robotic device that has a double purpose: to water plants and serve as an attraction to observers thereby creating amusement. It is designed as a little ship inhabited by a small 'captain' that is displayed as being in charge of the device's actions. The pilot interacts with various synchronized elements building up a narrative of being in charge of watering the plants. We first report on related work before describing the interaction concept in more detail. We then elaborate the technical implementation of the PWR focussing on mechanical and software aspects.

1 INTRODUCTION

Building on our ethnographic fieldwork in residential care homes and the literature, we know that not only physical care tasks are crucial for the health of older people but that there is a wide range of aspects that contribute to the well-being of this vulnerable group as well (Rissanen, 2013). Two of the overriding themes, which are rarely mentioned in the scientific literature, is the lack of indoor plants on the one hand, but also the monotony of everyday life caused by the constant routine of institutional procedures on the other. In the present paper, we report on the general concept and the technical development of the PWR prototype as part of the ReThiCare project, which uses an exploratory and co-design approach to rethink the design spaces of care technologies for elderly care (ReThiCare, 2021). We designed a robotic device that has a two-folded purpose: It shall on the one hand – and also as a pretext – take care of watering indoor plants in a care home. On the other hand, it is intended to attract attention through its playful design, nautical narrative and internal interaction behavior of the pilot (or 'captain') interacting with the ship, thus distract from the everyday routines of older people in care homes (see Fig. 1 and 2). By implementing a small robotic pilot on top of the robot, that is displayed as being in control of the actions of the device, we hope to build an illusion of distributed agency within one robotic device. We propose to use the term distributed agency to describe the perception of a user where a robotic device is not perceived as a uniformly acting device, but rather as a machine controlled by a robotic agent. We hope that this puts the human counterparts into an observer's position and thereby relieve them from possibly pressuring expectations (i.e. to interact with the robot directly). Additional elements on the robot, each of them contributing to the robot's choreography, serve as a possible source of information for the audience about upcoming actions of the robot and are aligned to the overall nautical narrative.

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For example the rotating radar is supposed to inform about the search mode of the robot whereby it navigates through the room searching for plant pots. The watering process is then depicted as being controlled by the little pilot. We hereby offer a new interaction concept for service and logistic robots in the context of elderly care that combines a logistical (or utilitarian) task with the social need for amusement and distraction from daily routines in a synergetic way.

Figure 1: Screenshot of the videoprototype showing a use case scenario of the Plant Watering Robot in a care setting.

Here, we first explain related work regarding the watering task, the aspect of amusement and activation robots for older people, and then focus on the aspect of distributed agency and attribution of expectations on a robot. We then present our concept of the Plant Watering Robot (PWR) alongside its interaction concept and elaborate the mechanical implementation and the behavior planning in detail. We conclude with remarks on the planned empirical testing of the robot in a real-life setting and possible scopes of analysis.

2 RELATED WORK

While there are a lot of different robotic approaches for the purpose of elderly care, only a few, like the robotic seal Paro (Klein et al., 2013) appear to really fit into the actual field of care. As we know from studies, the use of Paro relies on active deployment by a caregiver, who situates the robot in the interaction with People with Dementia (PwD). This is obviously also the case for simpler care technology like lifting devices, which can have an over straining effect for the residents as those work directly on the body (Hornecker et al., 2020). As we wanted the PWR to function without caregivers supervision we decided to construct a use scenario in which the robot does not directly interact with the user but only is observed by them. By avoiding focused interaction that eventually entails verbal dialogue or even direct body contact, we hope to foster the robots functionality when it is sharing the same space with elderly or PwD.

The task of taking care of plants, i.e. by watering them, is widely addressed by the sub-field of farming robotics. On the smaller scales of our context given, namely the watering of houseplants, we found only a few similar projects. The “Plant Watering Autonomous Mobile Robot” by Nagaraja et al. (Nagaraja et al., 2012), for example, consists of a robotic platform with social cues, that acts on a hard-coded behavior script. Not only to make task performance more autonomous, but also to make the process of searching for plant pots more interesting to look at, we wanted to implement an autonomous and also each time slightly varying movement behavior. This motivated us to develop a more autonomous robot using a more flexible behavior planning, consisting of a search mode for plant pots and flexible motion planning. Also, in order to fulfill the main purpose of the robot, the distraction of daily routines and serving as talking points to residents and visitors, we consider it important not to implement a strict movement trajectory but to establish navigation in a varying but intentional manner.

The most important source of inspiration for our study was the CERO project (Hüttenrauch et al., 2004; Severinson-Eklundh et al., 2003), which implemented a small character on top of a service robot giving feedback to user’s input and thereby complementing the interface. The movement of the small character was synchronized to the spatial behavior of the robot in order to make its movement trajectory more predictable for human counterparts when encountering it – for example, the character rows its arms according to the speed of the device. The additional feedback given by the small character in an abstract but familiar way enhances its readability and thereby makes the robot better aligned to its social environment. The pilot serves as a subject of agency attribution that is separated but still connected to the rest of the robot’s body.

Recent years have seen significant progress in technologies for mobile robots driven by the open-source Robot Operating System (ROS) framework. This has resulted in the development of frameworks such as move base (Zheng, 2021) for navigation on mobile robots. Further, deep learning developments in the past decade has also significantly improved the perception and interaction capabilities of the robot (Pierson and Gashler, 2017). This has resulted in the development of object detectors (Wu et al., 2019) or pose estimators (Deng et al., 2021), thus enabling robots to detect and approach the objects such as plant pots. We make use of these state of the art technologies in the development of this plant watering robot.

3 THE GENERAL CONCEPT OF THE PLANT WATERING ROBOT

It is well known that people's general well-being depends not only on their basic physical needs (the so called existential needs) but also includes social, spiritual, and cognitive needs. We also know from studies, that the presence of plants can contribute to the "psychological and social well-being" in elderly care settings (Rappe and Linden, 2002). Although scientifically not fully explained, the presence of "indoor plants can provide psychological benefits such as stress-reduction and increased pain tolerance" (Bringslimark et al., 2009). This is also taken into account in many care homes, although it is additional work that often falls behind the core activity of care work. Another factor of current care work, which we identified in our field research and which we would like to address, is the generation of distraction from the monotonous daily routine people living in care homes often experience. The PWR answers to those two identified but distinct needs, the lack of plants, and the lack of distraction from daily routines, in a combined way: It is not only supposed to help maintaining plants in a care home, but it should firstly entail a nice-to-watch process and serve as a talking point, residents, care staff or visitors may talk about when encountered.

By doing so we try to bring back more organic but also more social life into care homes – thereby fostering the well-being of older people.

With the PWR, we propose a new interaction concept, that is based on the idea of evoking a distributed agency attribution on one robotic device. We hereby hope to overcome the predominant view of robots as one holistic actor with a unified body. As depicted (Fig. 2), the PWR is designed as a sort of deep sea vessel with a propeller that is controlled by a small pilot, a myKeepOn. The myKeepOn is a robotic toy based on the research robot KeepOn, built by Hideki Kozima (Kozima et al., 2009), and is widely acknowledged for its universal social cueing capabilities. The following description is structured along two different perspectives, one decidedly social and one decidedly technical. While the social perspective focuses on the interaction concept and the overall nautical motive, the technical part focuses on the mechanical implementation of the single elements and explains the behavior control of the whole PWR in detail.

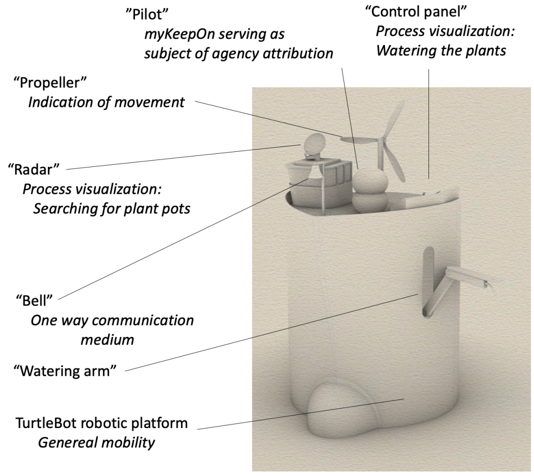
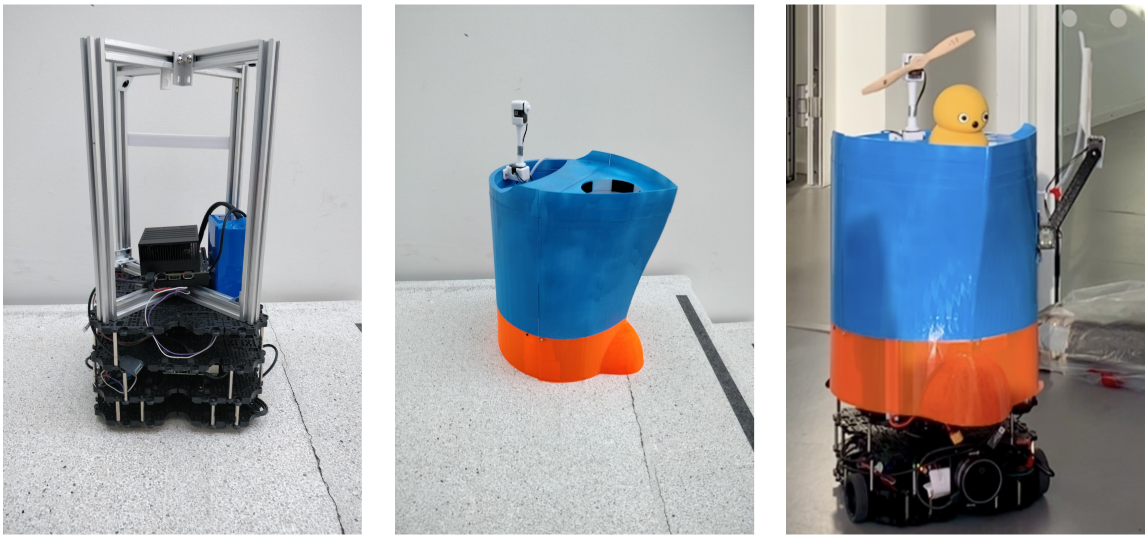


Figure 2: Technical overview of main elements.

3.1 Interaction Concept

We created a playful narrative with a nautical motive around the robot's form, actions, and behavior. That is the pilot driving around its habitat and taking care of the plants with the help of the ship which it controls. By evoking the ascription of different agency attributions on one robot, one social one (the pilot), and several non-social ones (the ship or vessel and the additional elements), we hope to build an illusion of a captain that navigates (or controls) a ship (Fig. 2). We try to foster this storyline aspect by adding five more elements to the robot, with which the pilot engages or that react to this engagement: a bell, a propeller, a radar, a control panel, and the watering arm. The whole choreography is coherently synchronized to the whole robot's motion and task fulfillment. We hope that this form of mechanical storytelling fosters the robustness of the robot in the socially complex care environment by enhancing its readability and predictability.

For the effect of evoking a control relationship between the pilot and the ship's elements, we consider it especially crucial to find the right composition of the elements interacting and – even more important – an appropriate and coherent timing. The PWR hereby also serves as a form of mobile stage (Lefeuvre et al., 2021) for the pilot and opens up a non-dyadic interaction structure that offers the user the position of a mere observer of a robotic theatre instead of a possible interaction partner in a focused and possibly overstraining interaction. It hopefully may be observed with joy and curiosity while it is present in care homes



a) Skeleton mounted on the Turtlebot. b) The PWR hull. c) Hull and skeleton assembled.

Figure 3: The main components of the PWR.

contributing to plant care but it can also be ignored. The ‘Ship’ is colored in typical deep sea vessel blue and red and has round portholes. Each additional element on the deck fulfills a role in the narrative of the robot’s behavior and task fulfillment: The propeller at the back of the ship indicates the actual and upcoming speed and direction of the robot’s movement. The functionality of this element leans on another boat association, the hovercraft. Building on this, we hope to use the propeller as a delayed but still coherent indicator for upcoming adjustments of the robot’s direction or speed. Although the propeller disrupts the motive of a deep-sea-vessel we hope it could be an intuitively readable concept for older people or maybe even for people with dementia. The watering process is visualized with the help of two additional elements, the radar on top of the cabin and a control panel next to the myKeepOn. The radar rotates while the robot navigates through the room indicating that the pilot is searching for plant pots. In order to break the predominant expectation towards robots regarding their fixed routine behavior, we implement a varying search behavior so that the pilot searches the same room on always different routes. The control panel visualizes the next step of the watering process: While the ship adjusts itself to the plant pot, the pilot turns to the control panel, indicating the upcoming start of the watering process itself. The watering arm was designed coherently to the nautical motive and detracts from the vessel when the watering process is being started by the pilot.

3.2 Technical Description

In this section, we describe the technical details of the current prototype. First, we present the mechanical structure of the robot, followed by the behavior control architecture and technical implementation of these behaviors.

3.2.1 Mechanical Description

The PWR robot from a mechanical perspective, consists of 4 major parts, as described below:

1. The ‘skeleton’, meaning the TurtleBot3 platform, which also holds an aluminium frame (referred to as the “aluminium skeleton”).
   The aluminium skeleton’s function is to attach the ‘hull’ to the TurtleBot3 platform. Now the hull and deck sit atop the aluminium skeleton. However, in the future, it will be mounted via 3D printed PLA mounting brackets. The aluminium skeleton is also mounted to the TurtleBot3 using 3D printed PLA mounting brackets. An image of the skeleton on the TurtleBot3 platform can be seen in fig. 3a.
2. The ‘Hull’, which is referred to as the robots shell. This part is the visible part which resembles the hull of a ship and hides the battery, the controllers, motors etc. (section 3.2). The shell itself has been 3D printed in multiple pieces of the material PLA on a Ultimaker s5 FDM printer. Hereafter it was glued together. For a future prototype, this shell will be upscaled and 3D printed in one piece. An image of the shell, by itself, can be seen in fig.3b.

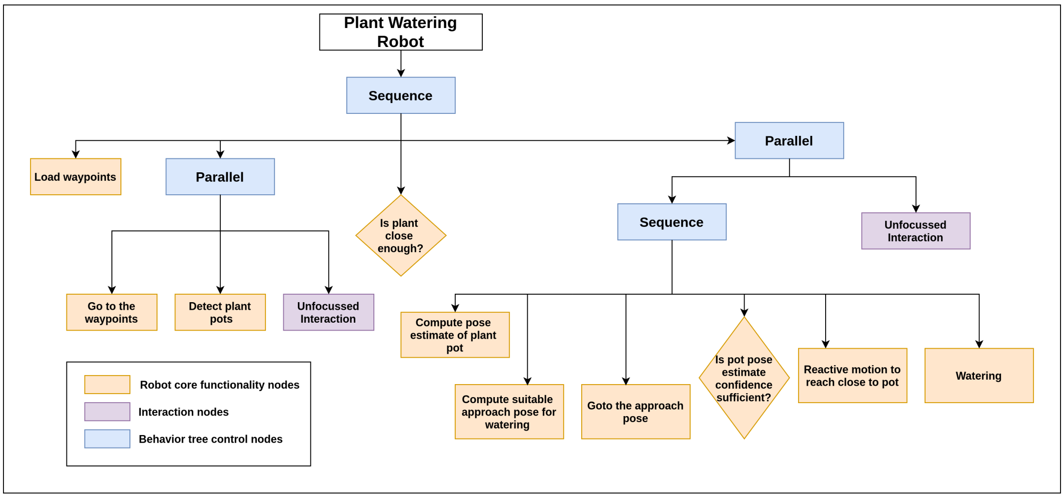


Figure 4: PWR behavior control architecture.

3. The 'Deck', which is the part that holds the moveable components for the narrative (section 3.2.2) parts and also the water tank. The deck is considered a part of the shell and can be seen mounted to the shell in section 3.2.2. The deck is 3D printed in two pieces and is also printed in PLA material, on the Ultimaker s5 FDM printer. The two pieces are glued together and then mounted to the top of the shell.
4. The narrative components, which are the movable components on top of the Deck, are controlled centrally. These parts can be seen in fig. 2 together with a small description of their function. A mechanical description is given in the following:

   The 'control panel' – This part will be added in the next prototype and will be 3D printed with PLA material. The control panel will have control able LED lights, for indicating watering on/off.

   The 'pilot' – This part is a myKeepOn, and it sits on top of the ship's deck and 'controls' the vessel. It is a simple soft robotic agent with a rubbery yellow surface and three degrees of freedom. It can yaw, roll and bounce. The propeller consists of two servo motors: one for yaw motion, while the other for the continuous rotation of the propeller arms.

   The 'propeller' – This part uses two servo motors, one for yawing the base of the propeller, used to indicate the direction of the PWR's motion behavior. The second servo motor is used to spin the propeller. The speed of the propeller spin indicates the speed of the PWR. The propeller mounting is 3D printed in PLA, and the propellers themselves are wooden.

   The 'radar' – The radar is 3D printed in PLA and uses a servo motor to rotate. This rotation indicates that the PWR is looking for plants to water and may not move on a clear trajectory. This part will be implemented in the next prototype.

   The 'bell' – The bell sits at the stem of the PWR, and rings when entering a room. The bell is mounted on a 3D printed tower, with a small metal bell at the end. The bell is rung using a servo motor connected to the bell via a steel wire. The bell will be added to the next prototype.

   The 'watering arm' – The watering arm sits inside the shell on the side of the ship. The watering arm has two servo motors, to give it two joints to be deployed and retracted. The structural parts of the arm is 3D printed using PLA. A tube runs from the tip of the arm to the water tank within the PWR. Here the tube is connected to a small pump, which is controlled by the Raspberry Pi board.

3.2.2 Behavior Control

The robot has a Raspberry Pi board as the main computer. All the basic planning and control algorithms such as navigation and manipulation run on it. All other components such as the two DoF arm for watering, the propeller, the radar and the myKeepOn are also controlled using this computer. In addition to this, the robot is equipped with the GPU enabled NVIDIA Jetson Xavier for running deep learning algorithms required for plant detection.

We make use of the behavior trees (Colledanchise and Ögren, 2018), for implementing the core func-

(a) PWR navigating from room to room looking around for plant pots

(b) PWR enters the room

(c) PWR approaches the detected plant

(d) PWR waters the plant

Figure 5: Plant Watering Robot (PWR) behavior overview.

tionalities of the robot such as navigation and manipulation as well as for the interactions described in section 3.1. Behavior trees provide an efficient way to combine multiple behaviors, while still ensuring a modular and reactive system. Fig. 4 describes the behavior control architecture of our robot using the behavior tree. Orange nodes are responsible for executing the core functionalities of the robot including navigation, detecting plant pots and watering while blue nodes are default behavior tree control nodes that are used to combine these different nodes to implement high-level behaviors. Purple nodes implement unfocused interactions by synchronising actions of the different components on top of the robot with the robot's general actions. These unfocused interaction nodes use several different components present on the deck of the robot thus resulting in multi-modal interaction.

The robot is first provided with a set of pre-recorded way-points in the environment. It navigates from one way-point to another looking for plant pots (see Fig. 5 (a) and (b)). For moving from one way-point to another (point to point navigation) it uses the move-base framework provided by ROS (Quigley et al., 2009) navigation stack. Plants are perceived using deep learning-based detectron2 (Wu et al., 2019) framework using a MaskRCNN (He et al., 2017) base for semantic segmentation and bounding box detection. The model is fully trained on PhotoRealistic synthetic data using BlenderProc (Denninger et al., 2019) without any manual annotations. Once the plant pot is detected, the robot tracks its full pose distribution using PoseRBPF (Deng et al., 2021) and starts approaching the plant pot (see Fig. 5 (c)). Once it is sufficiently close to the plant pot and has sufficient confidence about the pot pose estimate it starts the watering process (see Fig. 5 (d)).

4 CONCLUSION AND FURTHER WORK

In this work, we have presented the concept of the Plant Watering Robot (PWR), a robotic device that is supposed to evoke a distributed agency attribution while it is fulfilling its task thereby questioning the predominant conception of robots as unified and holistic actors (Krummheuer et al., 2020; Lefeuvre et al., 2021). By using additional non-social but symbolic elements on the robot with which the small pilot seems to interact, we hope to construct an illusion of control that puts the user into an observer's role thereby relieving him or her from the pressure of direct interaction with an unknown robotic entity. By using a coherent choreography with and around the robotic device we hope to evoke a poetic and alternative narrative – 'the pilot and its ship taking care of plants' – around the robot's presence and its functioning. We hope that this playful interaction design approach will help to explore new design spaces for robots in the context of care.

Our current prototype is able to perform the core functionalities of watering and indicating its movement and watering behavior. The next step of development will focus on designing and integrating the interaction scenarios described in Section 3.1 into the robots behavior. We will use video-based user studies in order to evaluate the coherence of the sequential order and find the appropriate timing of the synchronized activities of the pilot, the ship, and the other elements. After pretesting the PWR in a university setting, we plan to conduct field tests in an elderly care home. With the use of in-depth videographic analysis of the interactions, we hope to answer the questions whether the implemented interaction concept with a distributed agency can foster the acceptance and readability of a robot and at the same time evoke amusement in the residents thus contributing to the general well-being of older people.

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