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SYSTEM DESIGN OF WATERING ROBOT

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Abstract: *Researchers continuously expand the experimental fields of robots' usage. The interesting one of them can be connected with indoor plant care. Plant care is a set of systematic and continuous tasks, which have to be done precisely by the plan based on environment and plant state monitoring. Only people or potentially enormous static watering systems can take care due it nowadays. The main question of this study is if it is possible to develop a usable indoor robotic plant care system. The article describes the development of that kind of system from the point of view of system design. The task of watering was chosen as a basic ability of it. The aim of this study is not only to show a use-case but also a decomposition, a block's definition as well as final integration.*

Keywords: Robotics, ROS, System design, Integration, Watering

1. Introduction

Due to the progression of technology, there are new areas that enable more ambitious usage of robotics even in everyday life. One of those areas can be plant care. In order to be done correctly plant care consists of many repetitive but also continuous tasks such as regular watering, fertilization, plant state monitoring as well as environmental monitoring, protection against pests and diseases, and so on. Because of all that quality care needs necessarily to be done by an intelligent agent (IA). The IA is not only able to create and fulfill a list of particular tasks based on specific plants, environmental conditions, and needs but the IA is also capable of reacting to unexpected changes that affect the state of plants and has abilities to detect them. All of these requirements imply that robots such as IA can be just the right choice to solve a large number of problems in the process of automation of plant care.

The research on the existing robotic watering systems (see Podolinský (2022) for details) has shown attempts at experimental developments. However, these projects in many cases only don't emphasize the positive properties of robots such as the possibility of sensing and reasoning in selective care but also don't struggle enough with negative properties like demanding user interaction with the robot and robot's usage.

The main purpose of the study was a development of a robotic demonstrator which can be used as a plant carer. Only the task of watering was chosen as a basic ability of the system due to the general complexity of plant care. This article focuses on part of the project that contains the system design of the demonstrator as well as its final integration into a complex robotic system.

2. Task formulation

The aim of the project was to develop a new indoor watering robotic system based on an available robotic platform that is capable to fulfil a minimal useful use-case. The indoor environment contains predefined plants and tanks that are used as the source of water. The user has to inform the system about all necessary facts featuring plant care especially the periods of watering as well as the amounts of required water and lastly the environment. The main task of the system, on the one hand, is the creation of a work plan based on the current state of watering, and on the other hand, is to ensure that each defined plant gets enough

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amount of water in a defined period. The entire system ought to be easily configurated and it is important for the user to have information about the current state of work and environment.

From the point of view of the system design, it is essential to ensure a common team development by an adequate decomposition of the system into blocks where each crucial subtask is defined. Suitable interfaces have to be proposed between these tasks and blocks. It is necessary to pay attention in order to guarantee the system's adaptability, extensibility, and smartness.

3. Overview of the system design

The system is divided into three basic parts (fig. 1). The first part is the user interface (UI), the second part is the server and lastly, there is the robot.

The UI mostly enables a simple switching of the main states of the system – start and stop and also a remote control. The user can easily and indirectly set a configuration as well as work plans of the system by adding and setting items and their properties. UI visualize the data of items and the properties, the work plan, and the current state of the robot. The server controls communication between the robot and the UI and also it is used as central data storage. The data are divided into a tree of items having defined properties due to their easy extensibility. The server schedules the work based on the state of the watering and activates robots. The essential task is also monitoring each part of the system.

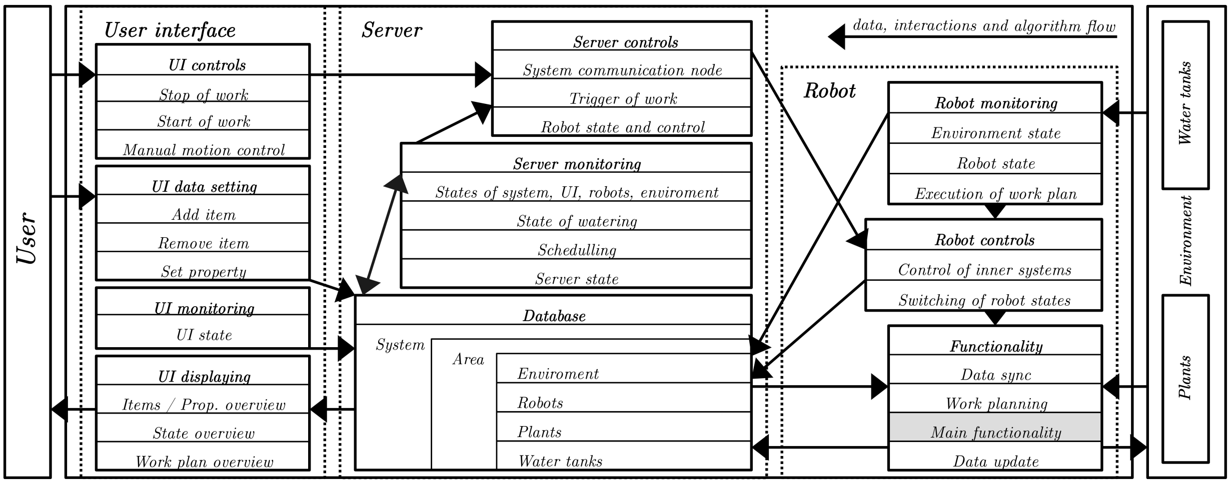

Fig. 1: The use-case study of the system

The robot is an end effector of the system which ensures the watering of the system. His work consists of an initial synchronization with the server, a creation of an optimized work plan - a sequence of watering and pumping of water, a main functionality, and a final updating of state data on the server.

The main functionality (fig. 2) is done in three phases in the loop. The system successively chooses the goals based on the work plan. In the first phase, the robot has to reach the almost predefined position of the goal. During the motion to the goal, a detection part of the robot searches actively the goal using computer vision. After the successful detection of the perspective goal, the system must approximately localize and identify it in the second phase. The pose from localization, which is done by computer vision, is used as temporary information about the goal position for motion planning. The identification is accomplished by detecting a predefined goal marker using computer vision. Because of an unexpected pose of the marker on the goal the robot must try to do a circular motion around the object at a defined distance. After the successful identification of a known plant, the type of goal (water tank or plant) chooses watering or pumping water as the next action for the third phase. The watering or pumping is done as a sequence of motions and watering platforms actions. If the work plan is fulfilled, the main functionality is finished.

The use-case definition of the system into the semi-synchronous sequence of the steps enables detailed technical and organizational decompositions. Each phase and step was carefully studied, and crucial subtasks were identified as final tasks for development. They are based on a model of independent nodes, which are implemented separately. Due to this model, the robotic framework ROS was chosen as a suitable platform

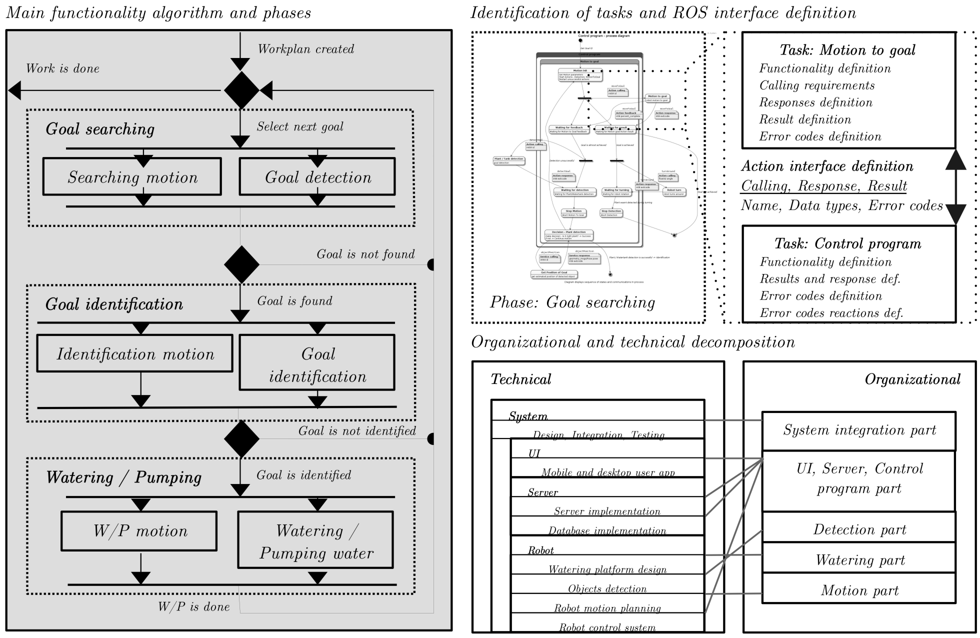

Fig. 2: The decomposition of the main functionality and system's blocks

for detailed further design. The highlight of it is a definition of the interfaces between each node. All types of ROS interfaces are used in the system - including messages, services, and actions.

The technical decomposition is a prerequisite for the organizational version due to the simplicity of a generalization of subtasks into similar or related groups. There are defined 5 blocks of subtasks (see relations between technical and organizational blocks in fig. 2). The high-level block UI/Server/Control program contains all tasks related to mentioned parts and the control program, which is in charge of ROS processes' control in the robot. Integration of high-level parts enables the independent and easy design of communication inter-block schemes, which don't include ROS, between them. The Detection part is responsible for computer vision and required sensor usage. The Motion part implemented path planning for the defined robot's moves. The Watering part is in charge of the development of the special watering platform for the robot, which enables water transport, pumping, and final watering. The last organizational block is connected with system processes (design, integration, and testing) and it is in charge of the successful common development of the entire system.

4. Development and integration

Defined subtasks were assigned to project developers of blocks. Details of proposed parts, specific used algorithms (e.g. Věchet (2010)), and implementation can be found in Bajer (2022); Dosedel (2022); Podolinský (2022); Sladký (2022); Vizvary (2022).

The complexity of the design and simplicity of the use of ROS enabled the simple integration of all developed subtasks into the system. Due to the number of developed functions, there were chosen a three-phase integration and testing (see fig. 3). In the first phase, the parts were tested in the simulation where were created the simplified model as well as the environment, the plants, and the water tanks. The aim was not just to verify the functionality but also to remove all inter-node bugs and testing of the sequence of the control program structure. In the second phase, the parts were tested using a smaller robot Leela, where the functionality could be verified in the real world. The final phase was the integration and validation of the entire system. The robot demonstrator was assembled onto a mobile robotic platform Breach, where a special watering platform was added. The server and the UI were successfully tested together with the robot too.

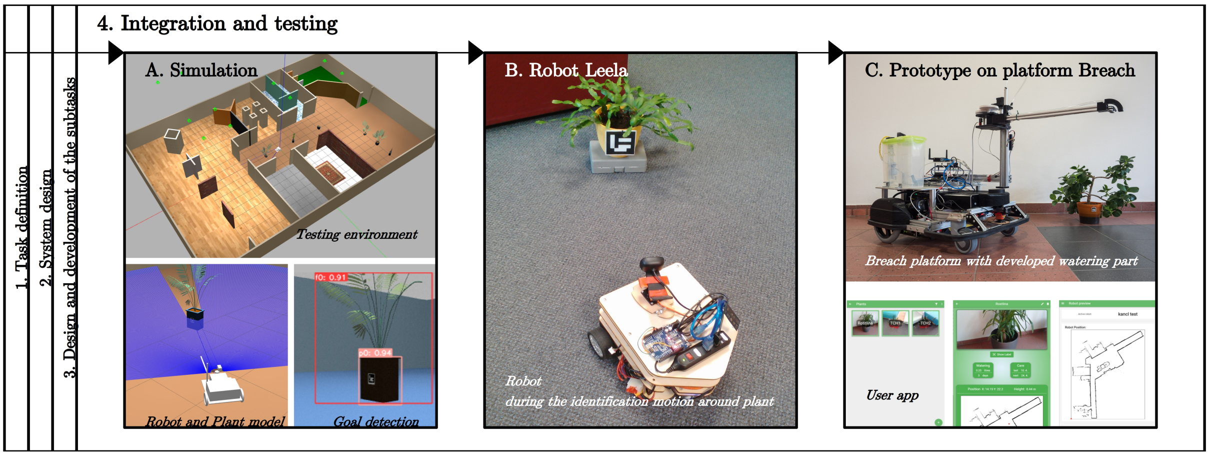

Fig. 3: Workflow of the development and the phases of the integration

5. Conclusions

The proposed complex system has been successfully created and tested in real conditions. Defined blocks are viable and enable further improvements as well as the possible development of new functionalities and easy integration into the system. Further development can be aimed at adding new abilities of plant care. The simplest one can be fertigation, which can be easily integrated into the developed watering platform. Adding plant state sensors (soil moisture, temperature, ph-meter, visual detection of dry leaves, and color changes) would be advantageous as well, due to the possibility of unexpected changes in the state of plants and ensuring full automation of care. Improvements in the platform will enable watering and monitoring of more difficult reachable plants in the environment.

The most difficult task can be the removal of the phase of plant identification using markers. A high increase in the reliability of plant detection and implementation of defined plant recognition is needed for it. An interesting task can also be the recognition of the required goal during multiple plants detection in the phase of motion to goal based on the fusion of the system and sensory data.

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