Smart Urban Garden

Software Engineering for Autonomous Systems

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Project Description

Smart Urban Garden is a project that leverages the power of IoT to nurture plants within indoor settings. This system aims to streamline gardening efforts by automating essential tasks, conserving water, and ensuring optimal conditions for plant growth. We create an automated ecosystem that employs sensors for monitoring crucial plant parameters such as temperature, humidity, light levels, and soil moisture. The primary objective of this system is to significantly reduce manual intervention, enhancing convenience while fostering an ideal environment for plant growth. By continuously storing essential plant data in a relational database, including temperature, humidity, and soil moisture, users gain insights into the conditions necessary for optimal plant health.

This system operates on a processing unit which collect data from various sensors and control actuators. These values will then be displayed on a web dashboard which allows users to know the environmental conditions of the plants when they check on them. The smart urban garden will be divided into areas in which the user can have different plants and conditions for the optimal growth and maintenance of the plant.

Goals of the System

1. Maintain a hospitable environment for indoor plants by providing and maintaining necessary:
   a) Lighting conditions
   b) Temperature conditions
   c) Humidity Levels
   d) Soil Moisture Levels
2. Offer an intuitive web-based interface accessible from anywhere, enabling users to monitor real-time environmental data.
3. Alleviate the need for constant manual care by automating plant care routines, including watering and illumination adjustments, freeing users from regular maintenance tasks.
4. Implement an intelligent watering system that operates based on soil moisture levels, minimizing water usage by providing hydration only, when necessary, thereby contributing to efficient resource utilization.
5. Encourage sustainable gardening practices by optimizing resource utilization, minimizing water wastage, and fostering a greener environment within indoor spaces.

Functional Requirements

Requirement Name	**Description**
Intelligent Watering Mechanism	Utilizes soil moisture sensors to regulate watering, ensuring efficient use of water resources.
Intelligent Light Adjustment	Utilizes light sensors to regulate light intensity, ensuring efficient use of light resources.
Intelligent Heating Regulation	Utilizes temperature sensors to regulate thermostat, ensuring efficient use of heating resources.
Intelligent Humidity Regulation	Utilizes humidity sensors to regulate humid level, ensuring efficient use of Humidifier.
Automated Plant Care	Automates routines like watering and light adjustments based on plant needs, reducing manual care.

Remote Monitoring System	Offers a web-based interface for users to monitor real-time data on lighting, temperature, moisture, and humidity levels suitable for plant growth.
Alert System	Offers user text-based alert on Telegram if some sensor values record values beyond the threshold.

Non-Functional Requirements

Requirement Name	**Description**
System Reliability	Ensures the system operates consistently and accurately, with minimal downtime.
User-Friendly Interface	The web interface should be intuitive and easy to navigate for a diverse range of users.
Scalability	The system should be capable of handling increased loads and additional plants without performance degradation.
Energy Efficiency	The system components, especially sensors and watering mechanisms, should be turned off when not in work, to conserve energy.

Managed Resources

Managed Resource	**Sensors**	**Actuators**
Watering System	Soil Moisture sensor	Water Pump
Humidity Regulator	Humidity sensor	Humidifier
Lighting System	Light sensor	Smart Bulb
Heating System	Temperature Sensor	Thermostat

System Implementation

System Architecture

MAPE-K Framework - MAPE-K (Monitor, Analyze, Plan, Execute, Knowledge) is a framework used in autonomic computing, which refers to the self-managing characteristics of distributed computing resources. This framework enables systems to be more adaptive, efficient, and resilient. "Monitor" involves observing the system's operation and environment. "Analyze" refers to understanding and processing this information. "Plan" involves deciding on a response to the analysis. "Execute" is about implementing this plan. Central to MAPE-K is "Knowledge," which encompasses the information, models, and control strategies that guide the other four functions. This shared knowledge base is crucial for making informed decisions and adjustments. MAPE-K aims to create systems that can adapt to changes without human intervention.

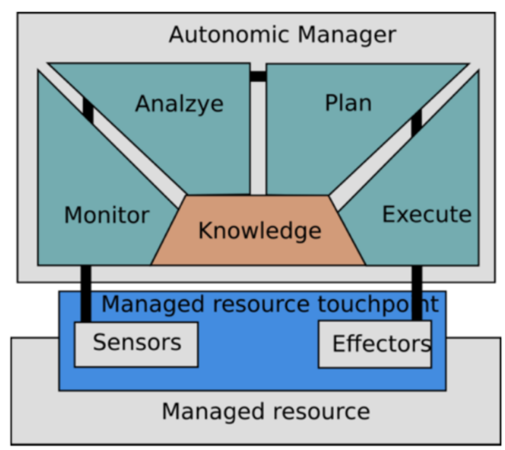
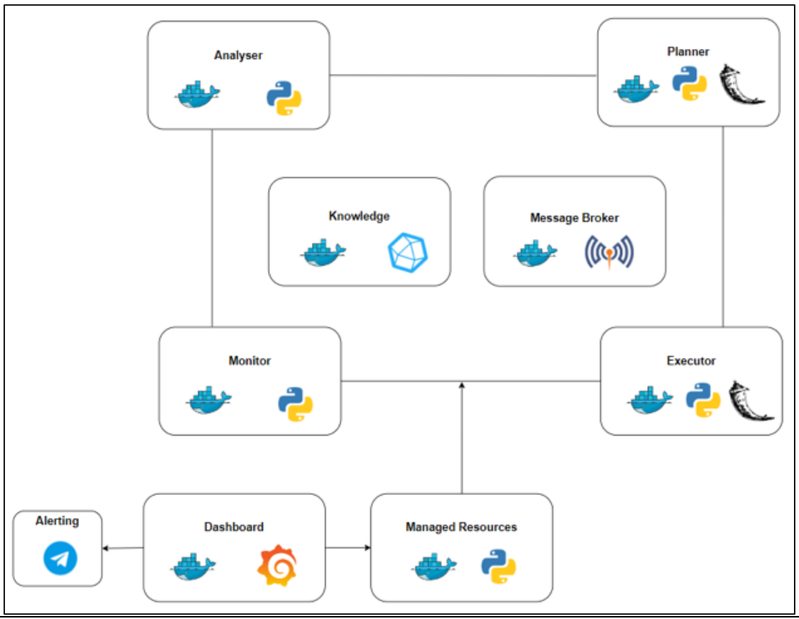


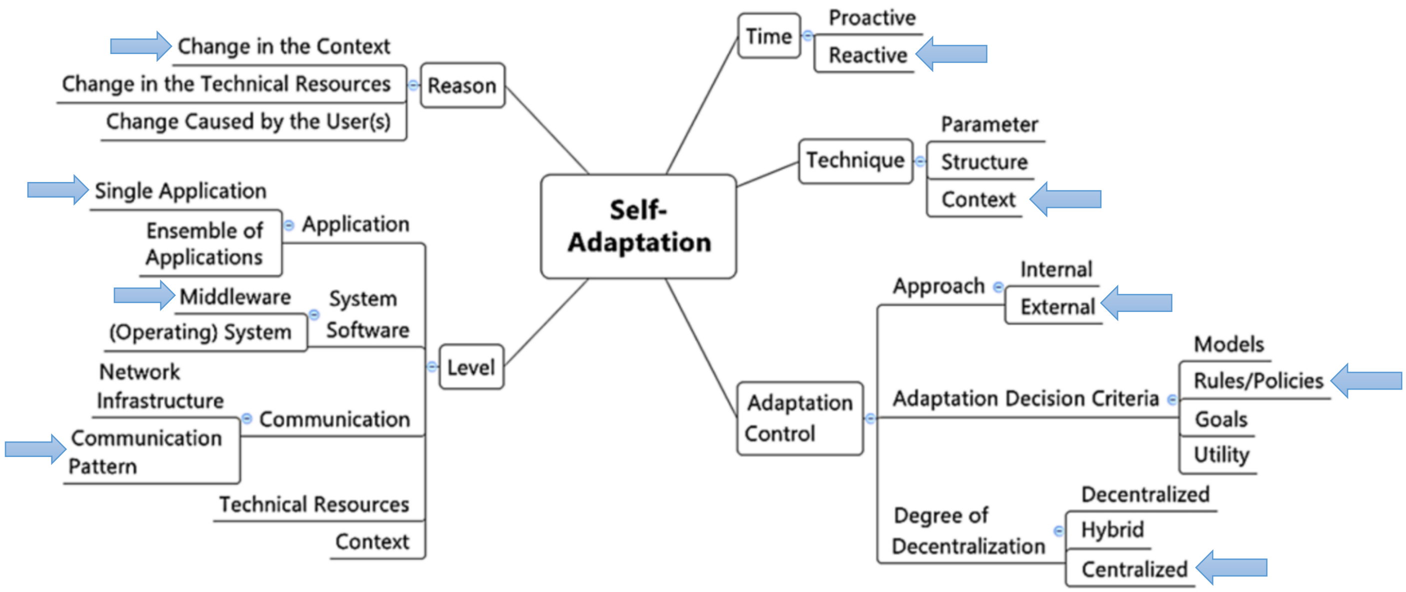
Figure 1: MAPE-K loop



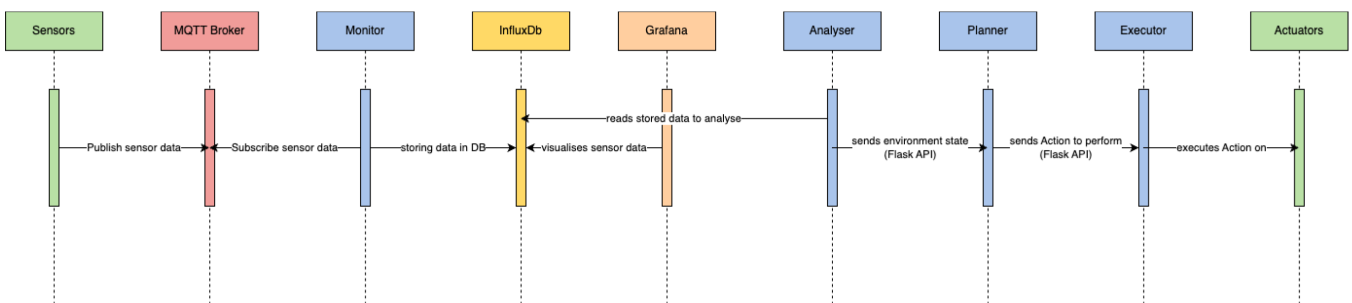
Component	Description
Monitor	Monitoring is achieved through various sensors that measure temperature, humidity, light levels, and soil moisture. These sensors continuously gather data about the environmental conditions affecting the plant.
Analyser	Analysis involves interpreting the data collected during monitoring. The system analyzes the data from the sensors to determine the current state of the plant's environment. For instance, it assesses whether the soil is too dry or if the ambient light is insufficient.
Planner	Planning involves deciding what actions to take based on the analysis. In our smart garden, planning occurs when the system decides whether to water the plant or turn on the light. This decision is based on optimal values for each sensor which are set as part of the system's logic.
Executor	Execution is the act of carrying out the planned actions. In our project, this is done through actuators like the water pump and the Smart Bulb. When the system decides that the plant needs water, it activates the pump; similarly, it turns on the bulb when needed. This ensures that the plant's environment is always optimal.
Knowledge	This aspect involves the information and rules that the system uses to make decisions. Smart Urban Garden uses specific knowledge like the optimal moisture level, light intensity requirements, optimal temperatures for optimal growth of the specific plant. A database with the above thresholds will be created for a variety of plants and shared among the MAPE components.

Self-Adaptation Architecture

Centralized Adaptation Logic - In this project, the centralized adaptation logic will be used for managing and optimizing the plant's environment. This logic will process data from various sensors to monitor real-time conditions like soil moisture, light levels, humidity, and temperature. It will then analyse this data against predefined thresholds and goals for optimal growth conditions for the plant. Based on this analysis, the system will make decisions, like activating the water pump or artificial lights, to maintain ideal conditions. This centralized approach ensures coordinated, efficient management of resources, adapting dynamically to changes in environmental factors, thus promoting healthy plant growth and resource conservation.



Sequence Diagram



Adaptation Goals

Goal Name	Goal Type	Actuator Used	Description
Optimizing Soil Moisture	Hard	Water Pump	Based on current moisture level, the water pump is either switched on or off.
Optimizing Light Intensity	Hard	Smart Bulb	Based on current light intensity, the bulb is either switched on with increased intensity or switched off.
Optimizing Humidity	Hard	Humidifier	Based on current humid level, the humidifier is either switched on with increased humidity or switched off.
Optimizing Temperature	Hard	Thermostat	Based on current temperature level, the thermostat is either switched on or off.

Decision Functions

Goal	Logic Condition	Action Taken
Optimizing Soil Moisture	Recorded soil moisture level is below the optimal threshold	Activate the water pump to increase soil moisture to the desired level.

	Soil moisture level exceeds the optimal threshold	Turn off the water pump to prevent further watering and avoid over-saturation of the soil.
	Soil moisture level is within the optimal range	Maintain the current state and take no action, ensuring ideal soil moisture for plant health.
Optimizing Light Intensity	Light intensity is below the optimal level	Increase artificial lighting to reach the required intensity.
	Light intensity is above the optimal level	Reduce or turn off artificial lighting to avoid excessive light exposure. Alert the user about the high light intensity.
	Light intensity is at the optimal level	Make no changes, maintaining the current lighting conditions for ideal plant growth.
Optimizing Humidity	Recorded humidity level is below the optimal range for the plants.	Activate a humidifier to increase the ambient humidity to the desired level.
	Humidity level exceeds the optimal range.	Activate a humidifier to reduce the humidity to a suitable level. Send an alert to the user indicating the high humidity condition, possibly suggesting additional actions or environmental adjustments.
	Humidity level is within the optimal range.	Maintain the current state and take no action, ensuring stable and appropriate conditions for plant health.
Optimizing Temperature	Recorded temperature is below the optimal range for the plants.	Activate the thermostat to raise the temperature to the desired level.
	Temperature exceeds the optimal range.	Activate the thermostat to lower the temperature to the desired level.
	Temperature is within the optimal range.	Maintain the current state and take no action, ensuring stable and appropriate conditions for plant growth.

Technologies Used

Python: Python is a high-level, interpreted programming language known for its simplicity and readability. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Python is widely used in various fields such as web development, data analysis, artificial intelligence, scientific computing, and more.

Mosquitto: Mosquitto is an open-source message broker that implements the MQTT (Message Queuing Telemetry Transport) protocol. MQTT is a lightweight, publish-subscribe network protocol that transports messages between devices. Mosquitto is commonly used in Internet of Things (IoT) applications for efficient and reliable communication between devices.

InfluxDB: InfluxDB is an open-source time series database designed to handle high write and query loads. It is often used for storing and analyzing real-time data, such as metrics, events, or sensor data. Its key features include high performance, ease of use, and a powerful query language.

Flask: Flask is a lightweight and flexible web application framework for Python. It is designed to make getting started with web application development quick and easy, with the ability to scale up to complex applications. It is known for its simplicity, flexibility, and fine-grained control.

Grafana: Grafana is an open-source platform for monitoring and observability. It allows you to query, visualize, alert on, and understand your metrics no matter where they are stored. It provides tools to turn your time series database (TSDB) data into beautiful graphs and visualizations.

Docker: Docker is a platform for developing, shipping, and running applications in isolated environments called containers. Containers package up an application with all of its dependencies, making it easy to deploy across different computing environments. Docker simplifies the management of microservices architecture and is a key part of many DevOps toolchains.

Conclusion

The Smart Urban Garden project represents an innovative and efficient approach to modern gardening, especially pertinent in urban environments where traditional gardening space is limited. By leveraging the power of Internet of Things (IoT) technology, this system significantly automates and simplifies the process of plant care, making it accessible and convenient for a wide range of users. The integration of various sensors for monitoring and controlling environmental factors like temperature, humidity, light, and soil moisture ensures that plants receive optimal care tailored to their specific needs. This not only promotes healthier plant growth but also conserves resources such as water and energy.

The project's emphasis on user-friendly interfaces and remote monitoring capabilities further enhances its appeal, allowing users to engage with their garden anytime, anywhere. The system's design for scalability and energy efficiency ensures its long-term sustainability and adaptability to different scales of operation, from small household gardens to larger urban green spaces.