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TITLE

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Submitted to Professor **Davide Di Ruscio**

Course Titled **Software Engineering for Autonomous Systems**

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# Introduction

An autonomous system combines sensors and control systems to enable complex sequences of operations that can be performed on different types of systems. The need to develop systems of this type arises from the need to be able to manage increasingly complex and constantly evolving systems. The advantage of this type of application lies mainly in the possibility of operating in environments without the aid of man or which require constant monitoring over time.

Despite the numerous advantages and benefits of such systems, various 'uncertainties' exist during their development. For example, one of these could be the danger related to their possible failures such as damaging an element managed by the system or the loss of human lives.

In general, any system is defined as autonomous if it respects the MAPE-K Loop, which describes the flow of data between its various components. Our MAPE-K loop is defined later.

The developed application represents an autonomous management system of a house.

The implemented system was developed in such a way as to respect all the aspects described up to now and applied in a specific context.

The first necessary requirement is therefore to have sensors and actuators, respectively able to collect data inside and outside the reference environment (an automated house) and to be able to monitor the data.

In particular, the trend of the following factors was simulated: external temperature (conditioned by the different weather conditions) and internal temperature (partially conditioned by the external situation, and by the insulation of the internal environment), external and internal humidity, internal light intensity and external, presence of people in the house.

Furthermore, the behavior following the activation of the various actuators which will change the environmental situation inside the house, in relation to the objectives to be achieved, was simulated. In particular, the following were simulated: an air conditioner (capable of increasing and decreasing the temperature), a dehumidifier (capable of increasing and decreasing the percentage of humidity), a sound and light alarm (capable of activating in certain situations), automatic shutters (able to regulate the brightness inside the house) and smart lighting.

The advantages of building such a system lie in the possibility of automating human behavior, to avoid errors deriving from distractions or negligence.

In Chapter 2 describes the objectives to be achieved using this application. In Chapters 3 and 4 instead, they are the technologies and system methods used are described respectively. Chapter 5 describes the implementation of the MAPE-K loop. In Chapters 6 and 7 the implementations of the various technologies and of the graphical interface were respectively described. Chapter 8 describes the results obtained from the running system. Finally, the conclusions are presented in chapter 9.

# Goals

We set out to develop an autonomous system for automated homes. Sensors have been identified within our system, such as:

* **Internal air humidity sensors.**

Humidity represents another fundamental factor inside a house, consequently it too must be constantly monitored.

It is affected by the dehumidifier. Using the latter, the internal humidity is increased/decreased in the correct way.

* **External air humidity sensors.**

Similarly, external humidity is also a useful factor for a home.

**CONTINUARE DESCRIZIONE**

* **Internal temperature sensors.**

Temperature is one of the most important factors inside a home. If this were to grow or decrease too much, there would be many problems, therefore it is an element to be kept in constant monitoring.

One type of actuator influences this quantity: air conditioners. If the air conditioners are active, the temperature tends to increase or decrease according to the set power.

* **External temperature sensors.**

The external temperature is also useful in obtaining a correct temperature inside the house. If you have a high temperature outside, the temperature inside the house will need to decrease; on the contrary, if the external temperature is very low, the internal temperature of the house will have to increase.

* **External brightness sensors.**

External light is useful for defining the internal light of the house.

**CONTINUARE DESCRIZIONE**

* **Internal brightness sensors.**

The internal light intensity is a factor to take into consideration because, if it is daytime, it is not necessary to have the lights on and on the contrary, if it is night-time, it is necessary to turn on the lights. For this purpose, automatic shutters and smart lighting are used, which allow you to dim/increase the light.

* **Motion/presence sensors in the house.**

Motion sensors make it possible to check if someone is in the house. An actuator is connected to them: the sound and light alarm. If it is activated, it means that an external, unauthorized person is at home. **CONTROLLARE**

In addition, several actuators have been identified, such as:

* **Conditioners.**

Physical system (simulated) able to increase/decrease the internal temperature of the house. It can take power levels that they range from to . **CONTROLLARE**

* **Dehumidifiers.**

Physical system (simulated) able to increase/decrease the humidity inside the house. It can take potency levels ranging from to . **CONTROLLARE**

* **Sound and light alarm.**

Physical system (simulated) able to detect dangerous situations inside the house. **CONTROLLARE**

* **Automatic shutters.**

Physical system (simulated) able to increase or decrease the lights of the house. **CONTROLLARE**

* **Smart lighting.**

Physical system (simulated) able to increase or decrease the lights of the house. **CONTROLLARE**

# Used technologies

The software has been completely implemented through the Python programming language and the use of the following technologies:

1. **MQTT**

The protocol used by the Mosquitto broker is MQTT. We used this messaging protocol to get data from sensors. Then we loaded the data via python to send it to the other components where the data can be fetched and processed from.

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Our published topics include:

* :indoor/nameRoom/light
* :indoor/ nameRoom/temperature
* :indoor/ nameRoom/humidity
* :indoor/ nameRoom/movement
* :outdoor/light
* :outdoor/temperature
* :outdoor/humidity

Where nameRoom can be: livingRoom, bathRoom, kitchen.

1. **InfluxDB**

InfluxDB is used to store the continuous flow of data coming and going through python files. The main benefit of using InfluxDB is the ease with which data can be sorted and found.

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1. **Telegraf**

Telegraf is a server-based agent for collecting and sending all metrics and events from IoT databases, systems, and sensors.



1. **Grafana (Dashboard)**

We used Grafana to visualize and understand the data. The main benefit of Grafana that we found was that, in addition to providing better visualization, it provides a way to create multiple dashboards at once which allowed us to better manage the information.



The MQTT messaging protocols have been used to exchange information between the system and InfluxDB. While Grafana was mainly used as a graphical interface and as a tool for interacting with the system.

# System functionality

Two features were implemented during development: reactive and predictive. The former group all those operations that allow the system to react to non-optimal situations that can arise inside the greenhouse during the day. The latter, on the other hand, groups all those features that are predicted based on the data collected and calculations made previously.

* 1. Reactive
* **Activation of Dehumidifier based on Humidity**: to regulate the process of increasing/decreasing humidity inside the house, the dehumidifier is activated/deactivated.

In particular, if the internal humidity exceeds the optimal threshold:

* if the external humidity is higher than the internal one and the dehumidifier is active, it is switched off.
* if the external humidity is less than or equal to the internal one, the dehumidifier is off, it is turned on.

If the internal humidity is below the optimal threshold:

* if the external humidity is less than or equal to the internal one and the dehumidifier is on, it is turned off.
* if the external humidity is higher than the internal one, the dehumidifier is off, it is turned on.
* **Activation of Air Conditioner by Temperature**: to adjust the process of heating/cooling the house the air conditioner is switched on/off.

If the internal temperature exceeds the optimal threshold:

* + if the outdoor temperature is higher than the indoor one and the air conditioner is on, it will be turned off.
  + if the outdoor temperature is lower than or equal to the indoor one and the air conditioner is off, it is turned on.

If the internal temperature is below the optimal threshold:

* if the external temperature is lower or equal to the internal one, the air conditioner is switched off.
* if the external temperature is higher than the internal one, the air conditioner is switched on.
* **Activation of Smart Lighting and Automatic Shutters**: If the light intensity is too strong inside the house, the smart lighting actuators are deactivated, and the automatic shutters are lowered in order to dim the light. Otherwise, if the light inside the house is too low, the shutters are raised, and the smart lighting is activated.
* **Activation of Sound and Light Alarm**: If there is a dangerous situation inside the house, the alarm will detect this particular condition and activate it.
  1. Predictive

These features are applied to the temperature, humidity, and external light as, not having a weather forecasting platform available, it is not possible to anticipate the trend of the atmospheric agents outside the house.

During the reactive phase we go to implement a plan only if a certain threshold is exceeded. During the predictive phase, on the other hand, the rooms are prevented from exceeding the established critical threshold by trying to predict what the future situation of the house will be and to keep all the rooms close to the optimal range for as long as possible.

Specifically, the application makes use of the system Knowledge to check the history of the plans made in the last month.

# System mode

System modes consist of the energy settings we have available; they are normally set by the user through the graphical interface, but they can also be set independently by the system. All the applicable modes and their characteristics are described below.

* **ECO.**

It consists of the energy-saving plan, as well as the default mode of the application. With the ECO mode active we limit the power of the actuators such as air conditioners and dehumidifiers.

* **Normal.**

With the Normal mode active we limit the power of the Air Conditioners and Dehumidifiers actuators. This mode, in a real environment, is on average more expensive than the ECO mode in terms of consumption, but at the same time manages to bring the system back into an optimal range more quickly and efficiently.

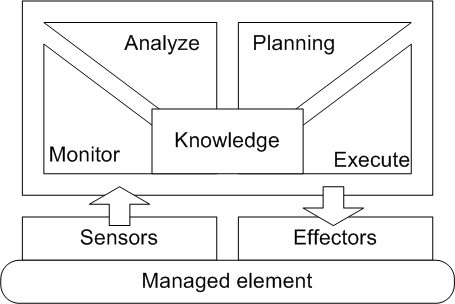
* **Optimal.**

This mode is the maximum that can be set in the system from an energy point of view and potentially the most expensive.

* **Dangerous.**

Danger mode is automatically set by the system itself if a critical situation is found. In particular, if inside the house some factors have exceeded the range of danger, the system will immediately set this mode and implement the corresponding plan to restore an optimal situation. The power of the actuators such as Dehumidifiers and Air Conditioners can also assume values that give the possibility of reaching ideal internal conditions as soon as possible. As soon as the optimal state is reached, the application will automatically reset the default mode (ECO).

# MAPE-K Loop Implementation



Our system is based on the MAPE-K Loop, as defined in paragraph 1, which describes the data flow between the various components:

* Monitoring: Component dedicated to recording data such as brightness, humidity, and temperature both indoors and outdoors.
* Analysis: Component that compares event data with knowledge base models to diagnose hypothetical dangerous situations and store them, but mainly correlates incoming data with historical data and acts accordingly.
* Planning: Component that considers the data monitored by the sensors to produce a series of changes to be made on the managed element. Interpret dangerous situations and/or currently available data to develop a plan, decide on an action plan and implement policies.
* Execution: Component that executes the change of the process managed through the actuators and executes the plan.
* Knowledge: Component that saves data, such as the days and time slots in which the house is most populated to track people's habits, to which all the other components refer.

# Implementation

# Graphic interface

# Results

# Conclusions