Efficient Air Conditioning Control in Smartsus KAAB :
An Object-Oriented Programming Approach

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November 28th, 2024

Object Oriented Computational Thinking

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Introduction

The Heating, Ventilation, and Air Conditioning (HVAC, for short) in Tec CCM is a complex, interconnected system of fan and coil units, pumps, cooling towers, and multiple circuits that all work together to keep the buildings cool and comfortable. However, because of the sheer amount of devices involved, this system uses a lot of energy. Still, if we constantly turn it off and on to save energy, the longevity of the devices will be damaged, which will be worse in the long run.

Our objective in this project is to find an automated solution to optimize this system to strike a balance between comfortability, energy consumption, and minimizing the number of cycles to conserve the equipment's longevity.

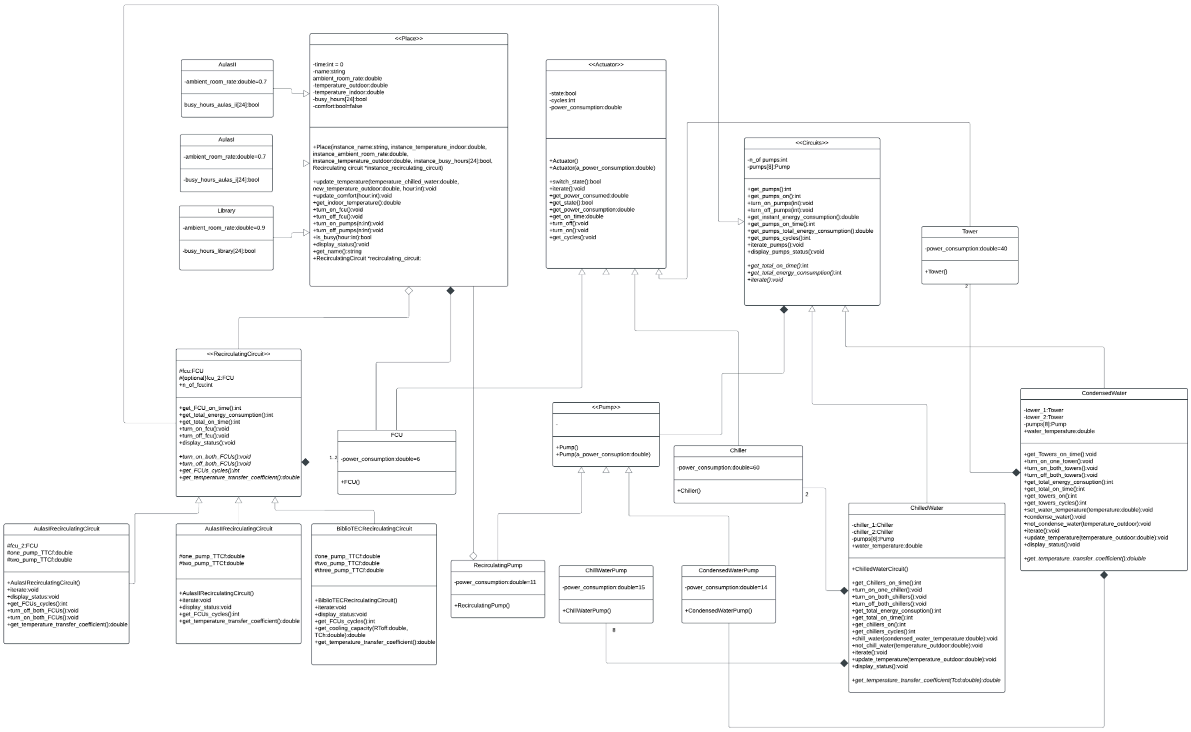
We solved this problem by coding a mockup of the air-conditioning system in the C++ language, using Object-Oriented programming to simulate each of the individual systems. A UML diagram was drawn to show how our code works and this report will show our method for optimizing the previously mentioned qualities.

Research

HVAC systems are crucial in regulating the indoor environments of buildings, the system heats the indoor environment if the outdoor temperature is too low and chills the indoor environment if the outdoor temperature becomes too hot. HVAC systems work by inhaling air from the outside, filtering it, and either cooling it or heating it depending on what is currently needed; it also expels air from the inside that has become stale and regulates air humidity indoors. All of this helps in achieving the comfortability and freshness that these systems are known for.

Since an HVAC system draws air from the outside, this can become a problem when there are extreme weather conditions because now the system will have to work overtime to achieve the same results. Naturally, this consumes a lot of extra energy; and dealing with this is a key element in making an HVAC waste less energy in *Optimizing HVAC Energy Usage in Industrial Processes by Scheduling based on Weather Data* written by Kashif Hesham Khan, the author suggests a way to improve the energy consumption of HVAC systems. If we preemptively automate the system to be on and off at specific hours, based on weather forecasts from that place at that time of the year, the people that work in specific rooms of the building at specific hours, and the magnitude of the task being done at the moment (e.g. the AC would be turned on with less power when people are doing office work, compared to packing work); we can find the best hours for the AC to be off, and therefore save as much energy as possible.

UML diagram and explanation



The code works as specified in the project, having Actuator, Place, and Circuits as abstract classes, and then having each of the specific classes like each pump, the FCUs, the tower, and the different buildings as child classes of all of the former.

Code

GitHub Code: https://github.com/Monknow/a-very-chill-project
Spreadsheet: Final C++ Project OOP

```
##### Aulas I RECIRCULATING CIRCUIT #####

   _____________ FCUs STATUS _____________

       # FCU I  Status: OFF Cycles: 6 On Time: 6
       # FCU II  Status: OFF Cycles: 6 On Time: 6
   _____________ PUMP STATUS _____________

        # PUMP 0: Status OFF Cycles: 6 ON Time 6
        # PUMP 1: Status OFF Cycles: 0 ON Time 0
   Energy Consumed:        66 W



   Energy Consumed:        102 W

########### Confort ###########
   Good Confort:   23
   Bad qsdf Confort:   0
##### Aulas II RECIRCULATING CIRCUIT #####

   _____________ FCUs STATUS _____________

       # FCU I  Status: OFF Cycles: 8 On Time: 8
   _____________ PUMP STATUS _____________

        # PUMP 0: Status OFF Cycles: 8 ON Time 8
        # PUMP 1: Status OFF Cycles: 0 ON Time 0
   Energy Consumed:        88 W



   Energy Consumed:        136 W

########### Confort ###########
   Good Confort:   23
   Bad qsdf Confort:   0
##### Library RECIRCULATING CIRCUIT #####

   _____________ FCUs STATUS _____________

       # FCU I  Status: OFF Cycles: 7 On Time: 7
   _____________ PUMP STATUS _____________

        # PUMP 0: Status OFF Cycles: 7 ON Time 7
        # PUMP 1: Status OFF Cycles: 0 ON Time 0
        # PUMP 2: Status OFF Cycles: 0 ON Time 0
   Energy Consumed:        77 W



   Energy Consumed:        119 W

########### Confort ###########
   Good Confort:   23
   Bad qsdf Confort:   0
Total energy.......... 1149 W
Total cycles.......... 70 ON/OFF Cycles
```

Results and conclusions

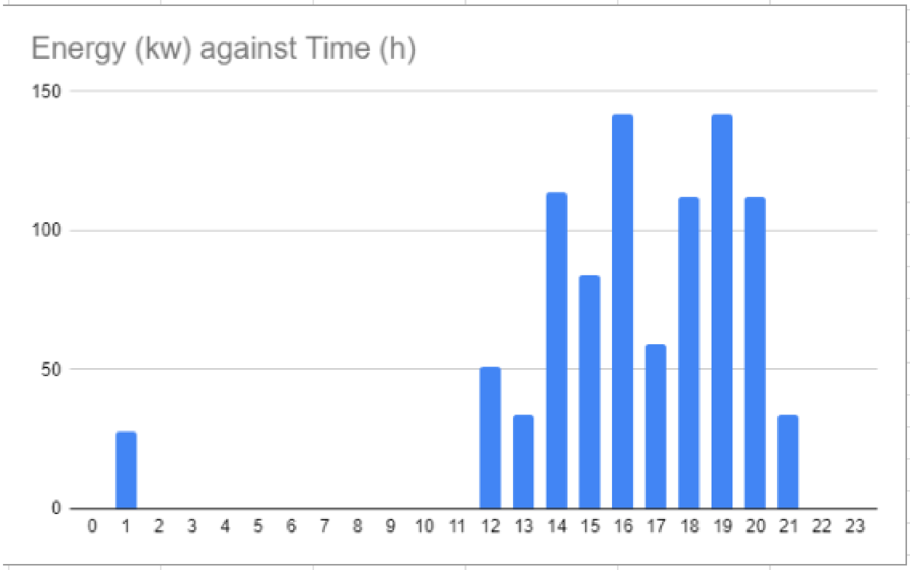
We coded an algorithm that activated every hour, it checked if it was currently busy in the building, and if the temperature was high enough for it to be worth activating more FCUs; if either of the statements were false, the algorithm did nothing and waited for the next hour.
This maximizes comfort in the building without compromising either energy consumption or equipment longevity.

```
void Place::update_temperature(double temperature_chilled_water, double
new_temperature_outdoor, int hour)
{
    temperature_outdoor = new_temperature_outdoor;
    time++;

    if (busy_hours[hour] && temperature_indoor > 18 && temperature_indoor < 23)
    {
        if (recirculating_circuit->n_of_fcu == 2)
        {
            recirculating_circuit->turn_on_both_FCUs();
        }
        else
        {
            recirculating_circuit->turn_on_fcu();
        }
        turn_on_pumps(1);

        double temperature_transfer_coefficient =
recirculating_circuit->get_temperature_transfer_coefficient();

        double temperature_delta = temperature_indoor - temperature_chilled_water;
        temperature_indoor = temperature_indoor - temperature_transfer_coefficient *
temperature_delta;

        recirculating_circuit->turn_off_fcu();
        turn_off_pumps(1);
    }
    if (busy_hours[hour] && temperature_indoor > 23)
    {
        if (recirculating_circuit->n_of_fcu == 2)
        {
            recirculating_circuit->turn_on_both_FCUs();
        }
        else
        {
            recirculating_circuit->turn_on_fcu();
        }
        turn_on_pumps(2);

        double temperature_transfer_coefficient =
recirculating_circuit->get_temperature_transfer_coefficient();

        double temperature_delta = temperature_indoor - temperature_chilled_water;
        temperature_indoor = temperature_indoor - temperature_transfer_coefficient *
temperature_delta;

        recirculating_circuit->turn_off_fcu();
        turn_off_pumps(1);
    }

    else
```

```
    {
        double temperature_delta = temperature_outdoor - temperature_indoor;
        temperature_indoor = temperature_indoor + ambient_room_rate *
temperature_delta;
    }
}
```

If we simulate an average day in México City, in which early mornings can be as cold as 8C° and noons 28C°, we can see how our projects keep each building temperature below the 25C° Comfort limit, and while it can reach it for instance, it will instantly recruit more Actuators to keep it down, all this while keeping energy and cycles low:

The peaks of temperature in the Library do not affect comfort, since they occur when the Library is empty, so we can save energy. Giving us just one hour when there are people in a building and the comfort isn't good, although just by a couple of decimals.



This project made us aware of everything that goes on in the background of HVAC systems and showed us a real-life example of Object-Oriented Programming.

HVAC systems are taken for granted in most commercial buildings; however they can easily be damaged by weather and continuous usage, they need a complex network and algorithm to function properly, and they consume immense amounts of energy–even when optimizing their use.

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