A distributed, collaborative development project of a Policy Engine for use in buildings

Global Software Development

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Abstract

background, however, ... what we did (the innovative aspects) contributions (design, evaluation) method results / what it means

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Chapter 1

Introduction

1.1 Introduction

The research field of building and home automation experiences a lot of growth - not least because of the promise to reduce energy consumption by more intelligent control, but also due to the possibility of heightened human comfort. Constructing resource efficient buildings makes sense, both in a political and economical perspective. In [10] it is stated that residential buildings use about 82% of the total energy consumption on space heating and water heating. Electric appliances uses 11%. Manually controlling an energy-saving policy is a time-consuming and inefficient task and the user have to know a lot of different equipment as well as information about the building. It is, however, achievable using building automation.

Regulating the environment of buildings to heighten human comfort, without annoying or irritating them [9] also requires that building components can communicate and be controlled in a fashion that seems smart or intelligent by humans. Buildings today might come equipped with a suite of sensors and actuators, opening up for a degree of customizable control, and our collective need is that buildings can adapt to the users and the sensor-perceived environment. We define a building automation program as a policy, and the software entity controlling policies we define as the policy engine.

Policies can be based on semi-static data, like time and weekdays. However this can have unforeseen and unwanted consequences. For example, a policy governing lightning activated merely by a static time schedule, might entail problems for people attending a rarely occurring late-night party in

the building. If the event calendar of the building is accessible to the policy engine, a conditional event-checking statement might ensure continuous lighting. However, in order to achieve a more fine grained control, sensory input is needed. We define the task of interacting with these policies, as residing with Facility Management (FM).

By employing a policy engine, with access to the buildings sensors and actuators, both the building owner, the users and the administrators of the building benefits from the automation provided. If policies are correctly defined, building owners save energy and natural resources while providing extra comfort to their tenants.

As stated in [1] *Worldwide, there is no doubt that efficient energy saving is only possible with modern BA based on networking in all levels of abstraction.*

Building users can experience a building autonomously adjusting its internal environment to suit their comfort and needs, while FM can achieve fine-grained control of the building.

This project was defined in the course Global Software Development at ITU. Our global development team consists of 5 students from IT-University of Copenhagen and 4 from Strathmore University, Nairobi Kenya. We have been provided a Building Simulator, making up for the lack of a real building. The complexity with integrating to hardware and communication protocols are therefore avoided, however the simulator has provided other complexities as will be evident later in this paper. The development focus of this project is therefore geared towards this simulator. The end product is a web-based management console, that allow for centralized flow control between sensors and actuators in the simulated building. This is achieved by implementing the policy engine that allows for automated actuator responses based on sensor feedback. An example at this would be closing the blinds in excess sunlight or turning of the heater when the windows are open.

In this paper we will;

1. distill requirements from course provided material and a non-exhaustive literature search on policy engines
2. develop a software solution that implements these requirements.
3. document the collaborative project between the IT University of Copenhagen, Denmark and Strathmore University, Nairobi Kenya.

1.2 Context

Modern buildings get ever more complex - from the type of materials being used, to the services and infrastructure they provide. Our focus in this paper is building automation through the use of governing policies, and therefore economically speaking, relates to the buildings running costs. Today the cost of resources such as gas, diesel and electricity have been generally climbing for the last many years, making it still more important to use them with care. Another cost related to the usage of energy and natural resources are the taxes which also are on the rise. However, economy is not the only factor for saving the planets resources. Today it is considered so good PR to 'go green' that some companies build a virtual presence for this subject alone [5] [3] [17].

A part of the whole 'go green' concept is to control your energy and natural resource usage. Many companies have many buildings that are either heated or cooled (or both), have lighting, appliances and server rooms to name a few. They may already be equipped intelligent heating systems, HVAC systems and AC's but many of these systems are typically proprietary and impossible - or very hard - to integrate with. As mentioned earlier this project integrates into a Building Simulator - which makes our task extremely simple compared to real work applications. We do not have to worry about actual sensor and actuator hardware, wiring, costs, communication protocols, existing protocols, coverage of wireless communication signals and so forth.

We assume the view that the Building Simulator *is* the building. Our system is therefore *open* compared to proprietary, since all it takes to access, for example, the temperature in a room is a http get operation with the building id and sensor in question. In real life settings a janitor might need to go to a room physically to check it's temperature, and adjust the heater in that room, several times a day to achieve and maintain the desired temperature. Our governing policies makes it up for a building janitor. Human staff starts out by defining the policies that the building needs. Then we can imagine the virtual janitor, issuing http get operations all day, to check the sensors mentioned in those policies. The policies consists of sensor-conditional behaviour that will adjust the actuators (by issuing http post commands with sensor id and the desired value) continuously.

1.3 Problem

The task of controlling the buildings likewise gets progressively more complex - especially if that control should be optimized in regards to both economic and human comfort. What good is a highly advanced building if the task of controlling it is just as complex?

We seek to design a system where FM can design the policies they believe is needed, based on their experience with the building. We do not expect FM to be IT experts, but we do expect them to be able to use a Internet browser and be familiar with the sensor id's used in the building

Our main consideration in this paper is; *providing a web-based infrastructure to visually define, manage and monitor the scheduling of governing policies for building subsystems.*

Attached to the above, we further want to point out these challenges;

1. The rating of proposed solution's usability
2. Policy time control and manual override
3. The use of complex policy datastructures on both frontend and backend

1.4 Learning Goals

The project in itself consists of two widely different aspects, namely Global software development and the policy engine. The new aspect in the project life cycle is for us to collaborate with team members distributed in different continents and countries, with many differences such as cultural and temporal.

These two aspects are also the ones where the main learning goals are derived from. In this regard the goals can be grouped into two different parts. The first being how to collaborate across different countries and the challenges that this would cause, including how to manage the team, how to communicate, how to increase performance and the likes. The secondary being how we can solve the technical project and deliver a working prototype of a policy engine, including creating the domain model, data structure, creating the actual policy engine in a object oriented-manner and tying this together with the visual and user friendly frontend.

One could summarize the learning goals to be: 1. How to work together in a distributed team and reflect on this and 2. How to develop a policy engine that conforms to the stated requirements (see Requirements).

1.5 Requirements

The overall requirements to the project are in a very open-ended manner, with only a few descriptive requirements to the product and process. These are:

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Product: The students analyse their solution from their chosen sensors and actuators requirements (and additional requirements they can think of) into functionality for their application. (30%) The students must design and implement a Web/Android application to monitor, control and visualize policies in a building. (20%) The students must describe and evaluate their solution as used by facility people as metrics. Additional metrics can be considered and will be taking into consideration by the examiners. (20%)

Process: The students should be able to write a proper, understandable and well organized report. (10%) The students should be able to reflect on a real world collaborative experience. (20%).

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Chapter 2

Related Work

2.1 Related work

A lot of research has emerged lately in the field of energy management systems for smart buildings. A similar work with the one presented in this paper has been done by Tiberkak et. al [20], where a Policy Based Architecture for Home Automation System is developed. The system is composed of five subsystems: one responsible for home automation, one for the local management of rooms, one for storing data, and a system for enabling communication between the first two sub systems. Different profiles are defined to improve energy efficiency. The concept of preferred and required profile is introduced, to differentiate between the preferences of a inhabitant and the maximum and minimum values of each environmental parameter in the required profile. Notifications and messages are sent between the layers when there is a change in the status of a room, and a appropriate decision is taken. Another approach is the one taken by Li et. al [14] where they implement a energy management system for homes, that provides automatic metering and capability of taking decisions based on monitoring energy consumption. Tasks can be used to specify different actions required at different moments. A simulation has been done for 1000 homes and by using their system, they achieved a significant energy reduction. In [8] a complete system for home management is described. Using ZigBee and IEEE 802.15.4, it is easy to add new devices, connect them with already existing ones and control them using a remote device. However, no kind of automatic management exists for the light service, heating and air conditioning. In [23] develop a prototyping platform based on Building Controls Virtual Test Bed

framework [19] for controlling and testing networked sensors and actuators on physical system. An algorithm for controlling the light and blind system in the room has been developed. The system is configured to provide an illumination of 500 lux between 6 AM and 6 PM. This has been achieved by measuring the daylight and setting the blind to block direct sun beam into the room. The system managed to achieve a reduction by an average of 17% of cooling demands and a maximum of 57% of lighting demand compared to the reference room.

Chapter 3

Method

3.1 Method

In this section, the workflow or working process used throughout the entire project is described. Furthermore we present how the collaboration was performed and which strategies we used.

3.2 Workflow

In our design of a policy engine, we decided to use an iterative design approach, both for the front-end and back-end. Using this approach we were able to continuously evaluate both the concept and our software. Throughout the development, we have done a lot of informal testing. The goal have been to continuously test and optimize the software and learn about the stability and performance and adjust the implementation accordingly.

For the front-end design an iterative design approach is commonly used. This allows designers to identify any usability issues that may arise in the user interface before it is put into wide use. Even the best usability experts cannot design perfect user interfaces in a single attempt, so a usability engineering lifecycle should be built around the concept of iteration. [15]

We ended up doing three major iterations:

3.2.0.1 1. Iteration

Model unit testing

3.2.0.2 2. Iteration

Servlet connection to web service and model utilisation

3.2.0.3 3. Iteration

3.3 Collaboration

Before any actual work could start, one preliminary goal was to figure out how we could make our group work together as one. Actually this challenge is even more challenging in this project than in a normal work situation: No organization is in order, no predefined roles, no actual project goals and the likes. This chapter will focus on these challenges and how we tried to handle these. We will highlight different methods to create social interaction and understanding. We will focus on how one can rationalize collaboration. Afterwards we will discuss the different tools we used throughout the project life cycle with collaboration in mind. Finally, we will discuss how one can manage a virtual project.

3.3.1 Social Context

When we discuss the *Social Context*, we discuss the direct milieu in which the person is and how different factors can influence this person. Communication is also a part of the social context, which is not necessarily only between two persons but can be between one to many persons, in different time zones, different cultures etc.

3.3.1.0.1 Common ground Our first step to connect to our fellow group mates in Kenya was to introduce ourselves via an e-mail and just shortly highlight some common information about each person from ITU, like stating

name, age etc. This method is known as creating “common ground”, as introduced by Olson and Olson [16]. The term to create common ground “refers to that knowledge that the participants have in common, and they are aware that they have it in common” [16]. Common ground is not only established through simple general knowledge about each participant. It is also created through a persons behaviour and appearance through meetings and conversations. We tried to use this method as a way of getting to know our team members, to create a level of understanding and finally to create a stepping stone from which the project could evolve from.

3.3.1.0.2 Trust and First Impression This initial contact was already quite frustrating because of the fact that it was difficult to get a reply from some of the group members in Kenya, only two members was relatively easy to get in touch with. This leads directly to two different considerations in our group work: “Trust” and “First impressions matters” [11]. Trust in group work is a value of high much the different team members trust in each other. How much does one believe that the other team members will deliver their part of the necessary work? How much does one believe that a mail we be answered? How well does the team work together? The trust is between the two subgroups, Denmark and Kenya, relatively low because of the amount -and lack of- replies and general communication. At the time being we only expect one member from Kenya to be online during our team sessions but at the same time we expect everybody from the ITU-group to be online at every session. This is also translatable from the first impressions that we received from the group from Kenya. It is not in any way rewarding for the group atmosphere not to join group conversations and not replying emails.

3.3.1.0.3 Collaboration Readiness The literature for these challenges seems to agree that these sort of problems generally arise from two different topics. One being “Collaboration- and Technology Readiness” and the other “Continuities/Discontinuities”. The latter part will be discussed in the section below, Groupware Technologies.

Collaboration readiness is a potential show stopper for the team work, if a given member is not ready to collaborate. This could be caused by having conflicts in interest, e.g. one is about to overtake another persons job or the likes. This could cause that the person, who is about to lose his job, would not be ready to collaborate. We have tried to identify these issues towards our fellow group members and we cannot find anything that should indicate that they would not be willing to collaborate. They should be just as

interested in delivering a good product.

One thing that could cause their lack of interaction in our e-mail correspondences and Skype meetings are the technology readiness. We know that it is a challenge for some of the group members to get internet access because of the fact that not all of them have a connection in their home. Our approach to solve this issue was to have a meeting each Tuesday at 10:00. This way we know that they should have access to their University, which most of the time has an internet access they could use. We know they should have time for this meeting, thus it is planned as a course on their schedule.

3.3.1.0.4 Ethnocentrism A potential threat to the well-being and harmony of the group is known as Ethnocentrism [2]. Ethnocentrism is a state of one subgroup, where the members sees that one group as the centre of everything, and every other group will be valued and ranked from this. A subgroup is a group inside a group, some of the group members are part of - but not the whole group is part of. This way it could create some sense of "Us versus Them", which is something you definitely want to avoid. One way to avoid this is to create multiple subgroups inside the group. One subgroup could be of everybody that likes football and know that they had this in common. If you are part of multiple subgroups the feeling of being part of just one group will dissolve, which should result in a more harmonious group. This way of creating subgroups would be something that you did early on during the initial communication, and something we tried to solve by writing small parts about each other member from Denmark. Unfortunately, we did not receive any feedback from Kenya. This has probably strengthened the feeling of us vs. them, because we do not know much about them. We definitely have a feeling that our group is the centre right now due to the fact that it is only the Danish group that develop and contribute to the project.

3.3.1.0.5 Coupling of work Coupling of work relates to the state of the current tasks and how loosely or tightly coupled they are. A completely loosely coupled work is one you can perform without the interaction and feedback from other persons, this could for instance be some of the work done at a large factory. A tightly coupled work task is, on the other hand, one you only can perform with other members of the group participating. Our project has evolved from a very tightly coupled project to a more loosely coupled. This is done on purpose. In the beginning of the project everybody had to be at the meetings because of the fact that we had to define which way to move the project. The development life cycle was quite rigid and strict.

After the initial phase, where we decided on the platform, chose an architecture etc., more and more tasks became slightly more loosely coupled. This means that one could start to work on his part of the project without any direct interaction with other team members. This would also allow such a highly distributed team as our to collaborate in an efficient way. It would just be to inefficient if everybody had to be together at the same time and place every time anything regarding the project should happen. As of right now we communicate through different Groupware Tools (see Groupware Technologies) and only meet through one weekly meeting.

3.3.2 Collaborative work

Collaborative work across cultures is a challenge. In our case we had to work together 9 people. 4 being from Kenya, a culture and country that we before entering this project, did not know much about. As mentioned earlier the social context and the process of creating “common ground” with the collaborators is of high importance. The goal is to create a fundamental shared understanding of the task and build up the motivation and very much needed trust for the collaboration to succeed. Cooperative work is defined by Schmidt as “People engage in cooperative work when they are mutually dependent in their work and therefore are required to cooperate in order to get the work done.” [18]

3.3.2.0.6 Articulation work The bigger the group the more ’articulation work’. Articulation work is the extra activities required for collaboration [18]. The task at hand defines what is the actual work and what is articulation work. Articulation work is about who does what, when and where. There are mechanisms of interaction that supports the process when articulation work cannot be handled through every day social interaction. These mechanisms are for instance: Organizational structures (formalinformal), plans, schedules and conceptual schemes. What all these mechanisms have in common is that they all strive to reduce the effort in labour, resources, time, etc. required to handle articulation work. Our strategy for the articulation work was to define processes and choose the groupware technologies that supported our cause best possible.

3.3.2.0.7 Coordination Increased “reach” of a task changes the coordination. The more spread out between people and artefacts a task is the more

the reach is increased. Segregation is a suitable strategy when a complex task is at hand. By dividing the complex task into smaller tasks you get to simultaneously solve them individually and thereby complete the larger complex task faster. It also allows for more specialised teams to investigate a task at a more detailed level. Therefore we segregated the tasks within our project into smaller more comprehensible tasks. Group members were assigned to these tasks that would work closer together until the task was completed.

To handle these tasks we created a project plan with deadlines and milestones to keep track of everything. Moreover we agreed on having a status meeting every week, where we would discuss progress, issues, ideas etc. Arranging a meeting where all is able to attend is not always easy. We did manage to all "meet" on Skype at times which took into consideration both the differences in time zones (temporal discontinuities, see Discontinuities) and the fact that people had entirely different classes and work schedules.

With computer supported cooperative work (CSCW), it's impossible to anticipate every contingency which might occur, there will always be exception handling. The core challenges and dimensions of cooperative work includes articulation work, adaptation of technologies and awareness. The lack of trust and awareness when you never meet face to face with your collaborators is problematic and requires methods and training when using communication tools. We primarily used Skype to communicate with and made sure to document changes and commits to the code base very detailed. Individuals working together need to be able to gain some level of shared knowledge about each other's activities.

3.3.3 Groupware Technologies

One way to describe *groupware technologies*, or collaborative software, is that it is a software designed to help people achieve a common work task within a group. One of the earliest definitions of collaborative software is found in the research paper "Rhytms, Boundaries, and Containers" by Peter and Trudy Johnson-Lenz. They describe the software as: "intentional group processes plus software to support them." [12]. The definition was first stated in 1974. A lot has happened since then, but the way a group collaborates and the group dynamics has not. Some general terms are still vital to discuss. We find the most importantly used terms in our project to be critical mass, adaptation and adoption process. These three terms and a general overview of the used tools will be explained in the sections below.

3.3.3.0.8 Tools Generally we used four different tools to communicate our teamwork and current progress; one synchronous and three asynchronous. We used Skype for every team meeting and for general communication between the members of the group. Skype is synchronous communication because of the fact that while using voice chat you will normally get an instant reply. We furthermore used three asynchronous communication methods, that is GitHub, Email and Google Drive. GitHub was used to share the actual projects current status by communicating via tickets what needs to be done. Email was used for communicating general group announcements, that we want to make sure that all of the members from the group receive. Lastly we used Google Drive to share important documents.

3.3.3.0.9 Critical mass Critical mass [6] is a sociodynamic that describes the necessary amount of people needed in order for a product to be a success. An obviously comparison can be made to the ongoing battle between the two social media platforms Facebook and Google+. Facebook has gained a lot of users throughout the last ten years, while Google+ struggles to compete with these numbers. The critical mass is best described by highlighting a real life example, which perfectly describes the term. The current situation of Google+ is that it is far behind Facebook, and we have no real use for it. Google are currently working on gaining a sufficient number of users that will make the product necessary for others to use. This is the goal of achieving the critical mass - to gain enough users for others to see the benefit and the reason for using it.

This description translates quite directly into our usage of groupware technologies, such as Skype and Google Drive. After selecting which tools to use to communicate between the different members, we have made a great deal out of actually using the tools. This has created the critical mass, in our group, for each tool, and every member knows that they can reach each other through these, and thus made it necessary for one to use.

3.3.3.0.10 Adaptation & Adaption Process Adaption and the adaption process [21] are two closely related topics that we briefly touched through our project. These terms describes how well an organization adapts a new technology and how they do it. Some of the problems with new technologies are that human beings tend to have rutines that are not that easy to steer away from. This results in a thought of “Why should I use this new technology, when it works perfect the way I use to do it”. One of the ways we tried to solve these problems was that we chose our tools as a group, and not by

enforcing it. This way the majority chose their favourite tool. The adaption process describes how an organization adapts a new tool: The first couple of weeks are extremely important for a succesful adaption. If the adaption does not succeed through these weeks it is very likely that the tool will fade out and never be used again. Our approach to this challenge has been that we pushed it to the people who did not know it, and tried to help them with the setup etc. An example of this could be the installation of Eclipse. One of the members from Kenya had some problems, and we all stayed online throughout the process and helped him install it. This way he could push it to his fellow team members in Kenya.

3.3.4 Virtual Project Management

Virtual Project management is about handling the entire project virtually where the users can access the project from any place and contribute seamlessly in developing the solution. We coordinated activities online through GitHub - handling the code base and reportingupdating issues as we moved forward. The mode of interaction has mostly been through chat and voice via Skype, and not through face to face meetings. This presented various discontinuities.

3.3.4.0.11 Discontinuities Watson-Manheim et al. [22] examine virtuality in terms of boundaries and discontinuities. They define discontinuities as “a break or gap in the work context,” or a “lack of continuity.” They proposed the concept of discontinuities as a general notion to permit a more comprehensive understanding of the many ways in which virtuality can be perceived. Distance is the most obvious boundary that is encountered in virtual work but it is clear that there are more boundaries such as time, organization, and nationality, which are not usually present in more conventional work settings to the same extent. It is only when those working in virtual settings perceive a boundary to be a discontinuity that it hinders work processes.

General properties of discontinuities are that they can emerge and change over time as people adapt in the teams. Discontinuities may only affect parts of the work. The typical discontinuities are temporal (working across time zones), geographic work location, work group membership (e.g. who you work with), organizational affiliation and cultural backgrounds. However discontinuities can also be expertise related (novice vs experts), historical

(different version of a product), different professions (e.g. developers and researchers) or different technologies.

In our group we experienced how the different cultural backgrounds can become a discontinuity. In Kenya if you show up half and hour or an hour later than the time agreed upon, it is seen as okay. While in the danish culture it is problematic. Also when asking Kenyans for feedback or criticism they are often fine with how it is, this might be because they don't want to cause problems and don't want to appear impolite. The concept of teams varies across cultures and organizations, and how teams are perceived will differ based on the organizational and national cultural attributes of its members [4]. It is also critical to note that individuals from different national cultures vary in terms of their group behaviors and communication styles [7].

3.3.4.0.12 Continuities Continuities are the opposite of discontinuities. Continuities are the stable factors in the collaboration that the participants are aware of and consciously act on, or they may be implicit and unrecognized. [22]. Continuities can appear to routine or be invisible in order to overcome discontinuities. Often continuities can be described as strategies or factors to overcome discontinuities.

Chapter 4

Design

4.1 Design

This chapter, is dedicated to the high-level design of the presented system. In this chapter we will explain the different concepts used in our policy engine.

During our brainstorm sessions it quickly became clear that we needed a policy engine that was flexible. With inspiration from other building management systems (see related work) and looking at the web service we had to communicate with, we came up with the concept of policies that consist of rules.

4.1.1 Policy

Merriam-Webster defines policy as; "A definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions."

We have defined a policy as a collection of conditional statements operating on sensors and actuators residing in the building simulator. The policy also has a start time and a stop time. It is also possible to de-activate a policy completely - without deleting it entirely.

It's in the statements that the power of our engine lies. A statement can either be a SetStatement or an IfStatement. The Set-statement sets an value in the simulator (in effect it is an actuator). It is possible to have nested If-

statements, making the policies both flexible and simple. An If-statement can contain multiple expressions that all are being anded when evaluated. If the user wants to make an If-statement with or between the expressions, she will have to use a nested if. The optimal solution to this would have been to make a safe left-recursive model. We did not have enough time for this, but we will elaborate further on this subject in the discussion (XX REMEMBER THIS XX). An expression can contain the following operators; < > <= >= != ==.

For example; lets consider an example where a rooms temperature should be adjusted.

[XX INSERT EXPLANATION XX]

Using this setup allows us to construct rules in a matter similar to other DSL languages such as SQL. Below is an example from a rule we can construct with our engine:

numbers

```
{"statements":[

// Define IF statement
{"type":"IfStatement","data": {"conditionalExpressions":[{"prefixOperator":"
    AND","aValue":
        {"type":"IntValue","data":{"theValue":10}},"operator":"EQUALS","
            sensorId":"ROOM1.TEMPERATURE"}],

// Define THEN statement
        "thenStatements":[{"type":"SetStatement","data":{"aValue":
        {"type":"BooleanValue","data":{"theValue":true}},"sensorID":"ROOM1.
            HEATER"}}],

// Define ELSE statement
        "elseStatements":[{"type":"SetStatement","data":
        {"aValue":{"type":"BooleanValue","data":{"theValue":true}},"sensorID":
            "ROOM1.BLINDS"}}]}}]}
```

What happens in this example is ...

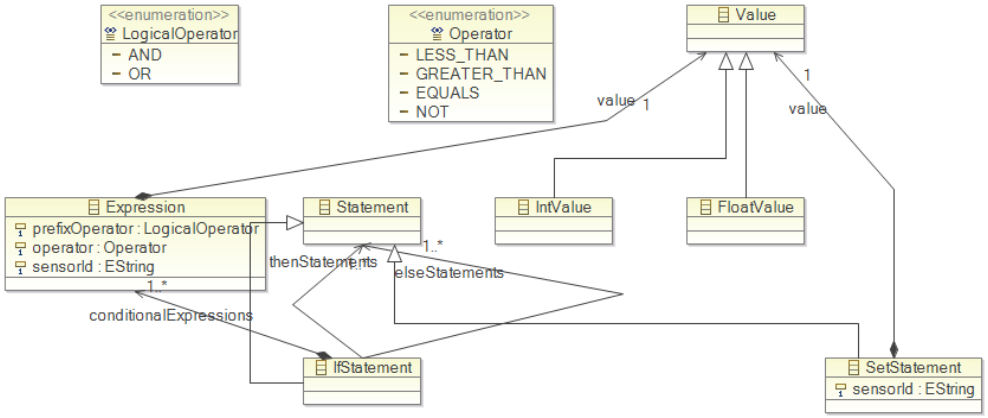

Figure 4.1: Model

4.1.2 High level design

4.1.3 Limitations

... Alternatives?

Chapter 5

Implementation

5.1 Implementation

This chapter is dedicated to the actual low-level implementation of the presented system. In this chapter we will explain in detail what has been implemented and how. We will give an overview of the whole project, explain how the different components communicate with each other and finally describe the flow - from creating a policy to applying it.

5.1.1 System

In this section we will elaborate on the implementation for this project. We will delve into the system that the project is running on. We will shortly discuss the technological choices we have made and explain our reasons so.

5.1.2 Interface Component

5.1.3 Abstraction Component

5.1.4 Storage Component

5.1.5 Request Flow

5.2 Front-end

5.2.1 Initial Ideas

The main idea for the user interface is to keep it simple and user-friendly without loosing advanced functionality. Initially we started making a rough drawing - so to better understand what we were dealing with (See figure 5.1). Doing so we tried to plan ahead on how the visuals could look like, the functionality, and how users would be able to control the policy engine.

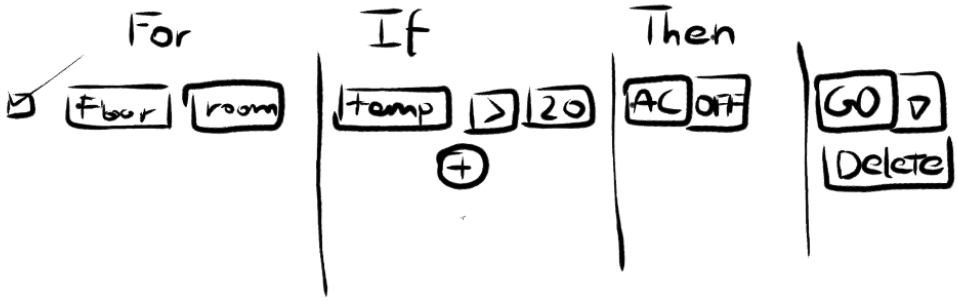

Figure 5.1: Drawing the initial idea of the element needed on the website, so a user can create, delete or modify a policy.

We quickly realized that our ideas could easily expand the project, with numerous functionality and features, that would bring the project to a far more complex level. We mapped all our ideas and prioritised them, and made a selection of ideas, which we planned on implementing.

The selected ideas included that:

- Users should be able to add, delete and modify policies.
- Users should be able to use complex operators in policies.

- Users should be able to create nested rules in policies.
- Users should be able to use wildcards in a policy (effecting for instance an entire floor without the need to specify the rooms that belong to the chosen floor).
- Users should be able to save policies and easily toggle an ON or OFF state.
- Users should be able to combine multiple sensors in a single policy.

The ideas were broken into three main front-end sites[1], from where the user can control the policy engine and overlook its operation.

The three mains are:

1. A site where a user can create, delete or modify -policies.
2. A site that visually represent the building digitally with floors and rooms (like a map used to navigate through rooms and floors).
3. A site that displays sensor values and group them in regards to the individual room they represent.

5.2.2 Usability

Seeing policies as rules for rooms in a building, with multiple sensors in each and every room, that can affect multiple actuators - not only in one room, but all of the rooms in a building: It leaves the user with a lot of selections. This will, if not represented properly, complex the process of adding new policies.

Following the principles of Steve Krug's "Don't Make Me Think: Common Sense Approach to the Web"[13], the functionality of a website should always let users accomplish their intended tasks as easy and directly as possible. Throughout the development of the front-end sites we have thrived to do so.

As an example, we have designed the process of adding new policies, as stepwise selections, instead of presenting the users with all the capabilities and elements at once. The task then looks simpler, and makes the flow of adding a new policy, more easy, and more direct.

[1] Front-end "sites" are dynamic HTML website.

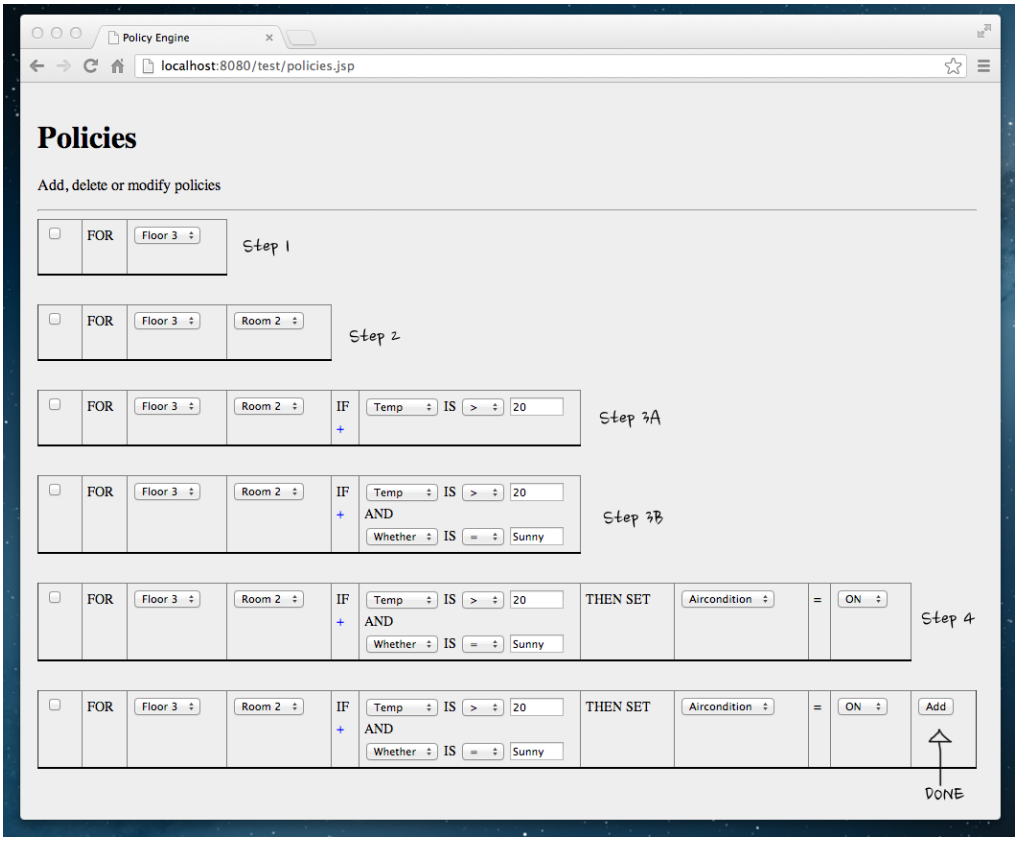

Figure 5.2: Illustrating the different elements introduced step-by-step. When the user has selected the first elements in "Step 1", then the elements in "Step 2" appears, and so it continues until a final "Add" button completes the process.

Another approach towards usability was using web elements like: Selectors and Buttons, instead of having textual policies, and thereby forcing users to write policy, using the keyboard.

For a developer textual editing and console commands might be preferred, and may somewhat be quicker, while they know the inputs by heart. But the intended users of our policy engine, are most likely not developers or fans of typing in commands. Also it forces users to memorize the inputs, and makes controlling the policy engine less intuitive. Therefore the idea was discarded and visual elements was implemented instead.

As for a future version of the policy engine, both methods could be implemented to function in parallel, giving a user both choices, and also the capa-

bility of copy and paste policies quickly.

5.2.3 Technology Choices

Why Java, benefits? due to policy engine with object classes etc. Original plan to use PHP expected it to be simple to use Java classed to handle the policies.

Chapter 6

Evaluation

6.1 Evaluation

In our project we have two areas that we have been evaluating. The first being if our policy engine is actually working and enforcing the defined policies. The other being the front end interface, testing to uncover potential usability issues that needed solving.

6.1.1 Policy engine system evaluation

6.1.1.0.13 Log testing Log every action and check timestamps, values, actions etc...

6.1.1.0.14 Unit tests .....

6.1.2 Usability testing

6.1.2.0.15 Think aloud test In a thinking aloud test, you ask test participants to use the system while continuously thinking out loud — that is, simply verbalizing their thoughts as they move through the user interface.

To run a basic thinking aloud usability study, you need to do only 3 things:

Recruit representative users. Give them representative tasks to perform. Shut up and let the users do the talking.

Cheap, simple, flexible....

Research shows that testing 5 persons uncover 80% of all usability problems...

REFERENCE "Thinking aloud may be the single most valuable usability engineering method." 1993, Usability Engineering, Jacob Nielsen

Chapter 7

Discussion

7.1 Discussion

In this section we are going to discuss our project in three different parts, one being the collaboration with the team members from Kenya, the other being the product and lastly the overall project. We have chosen to analyse each of these areas with an approach of highlighting what could have been done differently and perhaps in a better and more successful way. We will reflect on our choices made during the project and finally also on our learning outcomes.

7.1.1 Collaboration

The collaboration between the students at ITU, Denmark and Strathmore, Kenya, proved to be a rather challenging task. Only one person from Strathmore showed interest in the project, even though this should have been four persons. We believe that this is not caused by our approach towards the students from Kenya but instead by a lack of interest and willingness to work on the project. With that being said, there could have been multiple ways we could have achieved a better performing team. Our collaboration strategy is still in the early phases due to the fact that we as a group never got to create any real collaboration platform to work from. A natural next approach, that we have tried multiple times to do, would be to gather every team member for an online Skype meeting. This way we would be able to, during a discussion of the current project, to develop multiple different subgroups, see 3.3.1.0.4, in the team, and not just the two general subgroups as Denmark

and Kenya. With these subgroups in place, one would have a much better foundation and a more solid team.

7.1.2 Product

(It is difficult to discuss the product when it is not done) In the section product, we want to discuss our final product. Questions one could ask:

- What could be improved?
- Prototype?
- Future work?

7.1.3 Project

(It is difficult to discuss the overall project when we still have one month left) A general overview of the project:

- What was good?
- What was not so good?
- How would we approach collaboration in a new project? Do anything different?

Chapter 8

Conclusion

conclusion...

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Appendix A

Appendix

A.1 A.1. Requirements

A.2 A.2. Tests