



## **Web Geographic Information System for smart campus and facilities management**

Júlio Gabriel Chilela

University of Houston

Julio Gabriel Chilela, master student at Department of Mathematics in Faculty of Science and Technology at University of Coimbra.

Julio Gabriel Chilela is now in a special program at the College of Technology at the University of Houston.

This research was made to develop a WebGIS for Smart Campus and facility management. Oriented by Driss Benhaddou and Alberto Cardoso.

Contact: [juliochilela@gmail.com](mailto:juliochilela@gmail.com)

## 1- Introduction

In the modern world we have seen the density of population growing very fast in many countries, and along with this phenomenon, cities are growing exponentially. Many buildings are being built and with them technologies are being used to make the buildings' residents live comfortably. Cameras, sensors and other devices have been placed everywhere through these cities, collecting data and sending them to one central management station.

For the purposes of this research, a university campus provides, on a smaller scale, the various components found in any large city, thereby providing a model that could demonstrate its capabilities in much the same way. University campuses are already equipped with cameras, sensors, power plants, bus systems, and other departments that present differing challenges for testing the capabilities of a smart system for facilities management. Furthermore, a large university student population of around 40,000 students offers advantages for testing smart systems, such as the efficacy of the systems' ability to detect and normalize CO<sub>2</sub> levels and temperature control, as well as the gathering of massive amounts of data for collection and analysis. Moreover, large student populations assist in the testing of smart doors, which can manage high occupancy levels, identify intruders by eye scanning and face recognition among other capabilities. Another important point is the availability of university public transportation systems, providing necessary information for students in real time, and the energy management system on a university campus provides invaluable data from a central control location, assisting the smart system in decision-making, for example, in the consideration of energy storage capabilities in hazardous conditions.

## Context and objectives

This project intends to show the importance of Web Geographic Information Systems applied to smart campus and facilities management through the implementation of 3D building maps and to geo-spatialize all the devices that are part of a smart campus. These devices can be, for instance, cameras, sensors, solar panels, air conditioning, and lamps. The WebGIS will also provide resources for searching, manipulating, visualizing and representing information on different scales and colors of all devices.

Along with the WebGIS, the system will have a mobile application to allow users to interact with the smart campus and its facilities and to make the access of basic information about the campus easier, like public transportation information and sensors data.

Users of mobile applications can take pictures of malfunctioning infrastructure and send them to campus maintenance staff. They can also chat about the campus about the state of the campus, such as roads, hazards, and other occurrences. In addition, they have the ability to request room temperature or lighting changes in smart buildings.

Web Geographic Information Systems are integrated to provide maps in 3D of campus buildings and all smart campus information in layers. This system will allow smart campus administrators to interact with the devices installed in facilities around campus.

Maps can display the exact location of the device (floor, plan) and show its status (ubiquitous values, on/off) and provide the possibility of changing the status of the device. Maps are also filled with different colors to represent different information for the smart campus and to organize all the information about the smart campus in layers, as well as smart campus issues by department.

## 2- Literature review

### **Geographic Information Systems: An explanation**

In the set of information systems we find a very particular type named Geographic Information System (GIS). Geographic Information Systems are a combination of hardware, software and data geo-spatialized, made to manage, and save information geographically referenced.

In order to have great results, decision makers ran to GIS to visualize information categorized about many areas of the modern world.

Geographic information Systems are commonly used for:

**Measurement:** the knowledge of distance or the spatial(aerial) extent or volume of a feature or incident will be basic but important and, using proximity analysis, GIS can establish the distance of objects relative to a theme or to other objects. Any units of measurement can be deployed, finding statistical measurements such as sum, mean, mode and standard deviation.

**Distributions and relationship:** Spatial distributions of object may be either random and regular or clustered, and GIS have the functionality, usually via the use of the nearest neighbor analysis, to describe distributions in these terms. Using contiguity analysis, they can also calculate the relationship between differing distributions across the surface, spatial auto correlated.

**Network analysis:** This analysis applies to linear features such as transport routes, rivers, pipelines and cable networks. Analysis can establish least-costs routes, shortest path routes, and degree of connectivity, etc. Measurement in network analysis can be in terms of monetary units, distance, and time, etc.

**Temporal analysis:** Spatial changes can be in absolute terms or defined overtime. Thus, it is valuable to know, for instance, the varying rates of growth of an urban area over equal consecutive time periods, to identify the proportional changes in land use for a given area over time. The long-term collection of remotely sensed data greatly expedites time series analyses.

**Modeling:** This is a broad category that frequently includes “What if” scenarios or models which are developed to show what a likely distribution of an object might be given its known distribution in a sample area, and this can be done for past, present or future scenarios. Optimum location analysis is a modeling procedure that attempts to optimize the location of any activity based on known inputs of the principal production functions. Digital terrain modeling allows for the inclusion of the height dimension for GIS analysis of slopes, aspect, contours and volumes.

**Interpolation:** This is simply the generation of missing values based on a set of known values within a study area. For instance, if a series of spot heights (altitude) are known, then it is possible to interpolate contour lines for the same area. Interpolation can be applied to a wide range of measured values.

**Visualization:** In GIS, visualization is used to organize spatial data and related information into layers that can be analyzed or displayed as maps, three-dimensional scenes, summary charts, tables, time-based views, and schematics.

Different areas of the society use GIS to explore its capabilities, for instance, in Urban Traffic, GIS is frequently used for measurement and routes to know the distance between two points, as well as to know the short path to reach one specific location.

GIS are also used in prediction. For example, according to the historic behavior of a specific kind of animal, because of weather changes (temperature, precipitation and

humidity) it is possible to predict locations where the animal will go when the environmental conditions change. These kind of maps are known as prediction maps of multicriterial analyses.

In consideration of the slope conditions, temperature, precipitation, aspect and the distance from the rivers is possible to predict hazardous areas to live or to install one specific infrastructure in some chosen area.

A city's administrators call upon GIS for urban planning and cadastering. Because of the variety of resources that GIS presents, it is possible to register all the city's information, like the ownership of a portion of land (with geographic coordinates), as well as the facility to know how many portions of land one person has around the area.

Throughout GIS, it is possible to register wires and cables around the city, power poles, locations of interests and companies that are doing maintenance of different zones in the urban perimeter.

Spatial analyses and modeling processes in GIS are also used to choose the best area to build an infrastructure analyzing different variables such as proximity to the forest zones, slope, distance from urban areas, and exposure to the elements. This kind of information process is known as multicriterial analysis.

Visualizing data is also very important in the modern world. Throughout this feature, we can make accurate decisions while we have data visualization from GIS.

## WebGIS

A WebGIS is a Geographic Information System working in a network and obeying the World Wide Web's protocols. It does not work only for Hyper Text Transfer Protocol (HTTP), Uniforms Resources Locators (URL), Hyper Text Markup Language (HTML), Web sockets, JavaScript and so on. WebGIS structure may vary considering its systems' diversity.

Generally, WebGIS applications are tools that allow users to manipulate, interact, analyze, save, manage and exhibit all kinds of geo-spatial data, as well as edit data through the web map and visualize the results of operations.

The Internet removed the distance in cyberspace. Some of the reasons why WebGIS is so popular in the World Wide Web nowadays are:

**“Global reach:** Clients can share geographic information easily within their organization and with people all over the world if you wish.

**Large number of users:** Clients can share their apps with dozens, or even millions of users.

**Low cost per user:** The cost of building one WebGIS app is often cheaper than building a stand-alone desktop solution and installing it for every user.

**Better cross-platform capabilities:** Web apps, especially those built with Javascript, can run on desktop and mobile platforms running a wide range of operating systems, from Windows, Mac OS, and Linux to IOS, Android, and Windows Phone.

**Easy to use:** WebGIS apps typically incorporate simplicity, intuition, and convenience into their design. Therefore, public users can use these apps without having prior knowledge.

**Easy to maintain:** Web clients can benefit from the latest program and data updates each time they access a web app. The web administrator does not have to update all the clients separately.

**Diverse applications:** WebGIS has made building apps easier, so its applications have grown diverse. Unlocking the power of geospatial intelligence, it now reaches millions of homes, offices, and laboratories and millions of individuals.”

“For government, WebGIS offers an ideal channel for delivering public information services, an engaging medium for encouraging public participation, and a powerful framework for supporting decision making.

For business, WebGIS helps create novel business models and reshape existing ones. It enhances the power of location-based advertising, business analysis, and volunteered geographic information, generating tremendous revenue, both directly and indirectly.

For science, WebGIS creates new research areas and renews existing avenues of research.

In daily life, WebGIS helps people decide where to eat, stay, and shop and how to get from here to there.

Web mapping is the process of designing, implementing, generating, and delivering maps on the Web and its products. (ESRI, 2015)”

The final product known as WebGIS is an online map that can be the output of different spatial analyses or simply representation of data in the map. Smartphones, tablets and computer browsers are updated to be a client’s WebGIS map.



## Geospatial

Geospatial is a reference of located information on the earth, or in simple terms, information with coordinates. This information can be for instance, the position of a hospital around a province, a bus stop, roads of a country, or the outline of a city.

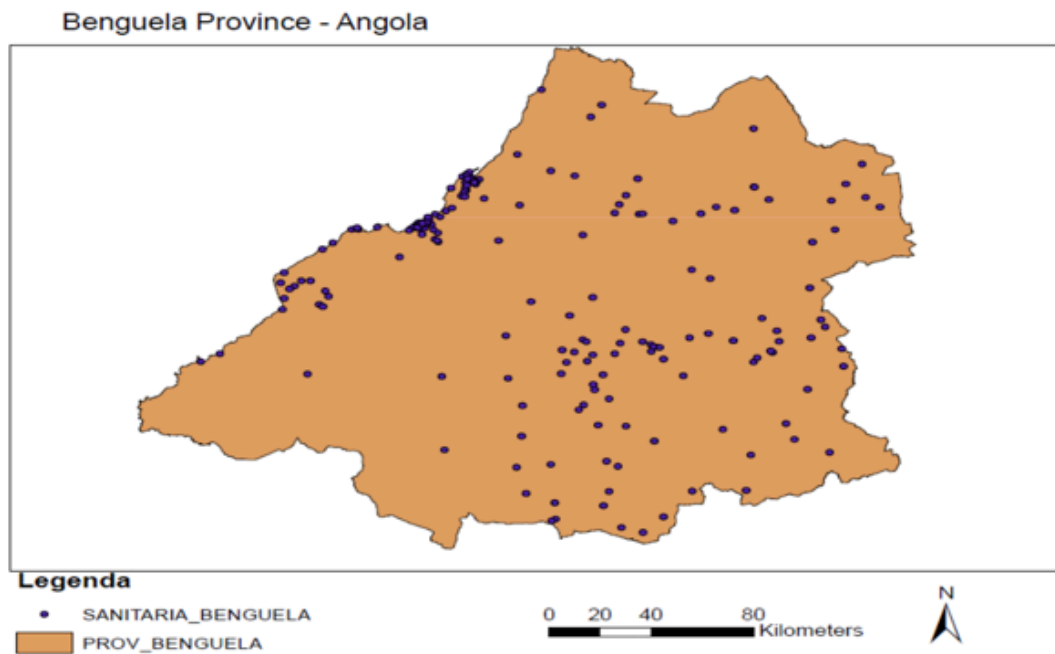


FIGURE 1: GEOSPATIAL CONCEPT. LOCATION OF HOSPITALS IN BENGUELA PROVINCE - ANGOLA

## Django

Django is a python web framework that makes the web development easy, clean and with a friendly design. It is simple to develop web sites in an easy way without needing to reinvent the wheel. Django is under open source license, without cost as well as freedom to use, copy, modify, distribute and free access to the source code.

Resources:

- Django is extremely fast. It was designed to help web developers finish their application faster and in the most practical way.
- Very safe: Django has a high security level. The security is a priority in Django.
- Scalable: Django can be trusted when used for a busiest website
- Extremely loaded: It has a large amount of extras that can be used to handle common Web development tasks. Django takes care of user authentication, content administration, site maps, RSS feeds, and many more tasks — right out of the box.
- Incredibly versatile: Companies, organizations and governments have used Django to build all sorts of things — from content management systems to social networks to scientific computing platforms.

## **GeoDjango**

GeoDjango is one of the Django modules that allows developers to work with geographic web frameworks. It makes the developers' life easy in terms of work with geospatial data in web applications.

The GeoDjango's goal is to make easy the way of the development of Web GIS applications, empowering the spatially enabled data.

Its features include: Django model fields for **OGC** geometries and raster data, extensions to Django's ORM (object-relational mappers) for querying and manipulating spatial data, loosely-coupled, high-level Python interfaces for GIS geometry and raster operations and data manipulation in different formats, editing geometry fields from the admin (<https://www.chicagodjango.com/blog/geo-django-quickstart/>, 2015 ).

GeoDjango intends to be a world-class geographic Web framework. Its goal is to make it as easy as possible to build GIS Web applications and harness the power of spatially enabled data.

GeoDjango is a very powerful tool for storing and manipulating geographic data using the Django ORM. It provides a simple API to determine distances between two points on a map, find areas of polygons, locate the points within a polygon, and much more.



FIGURE 9: Geodjango:

Source: <https://www.chicagodjango.com/blog/geo-django-quickstart/>

## **Bootstrap**

Bootstrap is a sleek, intuitive, and powerful front-end framework for faster and easier web development, created by Mark Otto and Jacob Thornton, and maintained by the core team with the massive support and involvement of the community (Bootstrap.com, 2015).

Bootstrap is a very popular HTML, CSS, and JavaScript framework for developing responsive, mobile-first websites.

## **Cesium**

Cesium is a JavaScript library focused on 3D graphics, in 3D globes creation and 2D maps, running specifically in web browsers with no plugins, and at the same time doing normal graphics.

The Cesium's first step were given by Analytical Graphics, Inc. (AGI), and its maintenance is guaranteed by an open source community.

It is a map library and JavaScript virtual globe. In order to obtain a hardware accelerated graphic, it uses Web Graphics Library (WebGL). It is independent from the web browser and operating system, and it is particularly designed for dynamic data visualization. It supports a 3D globe, 2D map, and a 2.5D Columbus view with special transition among views with one line of code.

It has resources to visualize dynamic geospatial data. Dynamic scenes from CZML can be animated in Cesium. It can visualize worldwide terrain from multiple sources and draw imagery layers using WMS, TMS, OpenStreetMaps, Bing, Mapbox, Google Earth Enterprise, ArcGIS MapServer, standard image files, ESRI standard and custom tiling schemes (United States Air Force, 2015).

Cesium is prepared to sketch polygons, circles, extents, billboards, ellipsoids, polylines, sensors, icons, labels, custom objects, and it consults material systems to change its appearance. The Cesium' camera is not static, and it has flight paths. For performance, it takes advantage of the low level geometric and rendering routines.

### 3- WebGIS Portal for smart campus and facilities management:

#### Practice case

In order to achieve the goal of having a geographic information system in the web capable of organizing, saving and geospatializing information for the campus, Django-Framework was used as the main technology in order to fulfill this objective. Considering its huge number of resources, security and capabilities to make the web development easy and friendly, Django-Framework was picked as a main web development tool to reach the goal.

Django-Framework combined with Cesium was used to build the entire web-portal and all its pages. In the image below, the main page of the website can be seen.



Figure 2: Main page

Along with Django framework and Cesium library, bootstrap was used to stylize and provide the main appearance of the website, providing the best appearance through its combination with CSS and JavaScript to make the navigation in the website easier, intuitive and interactive.

In the images below the website architecture is presented along with the content organization.

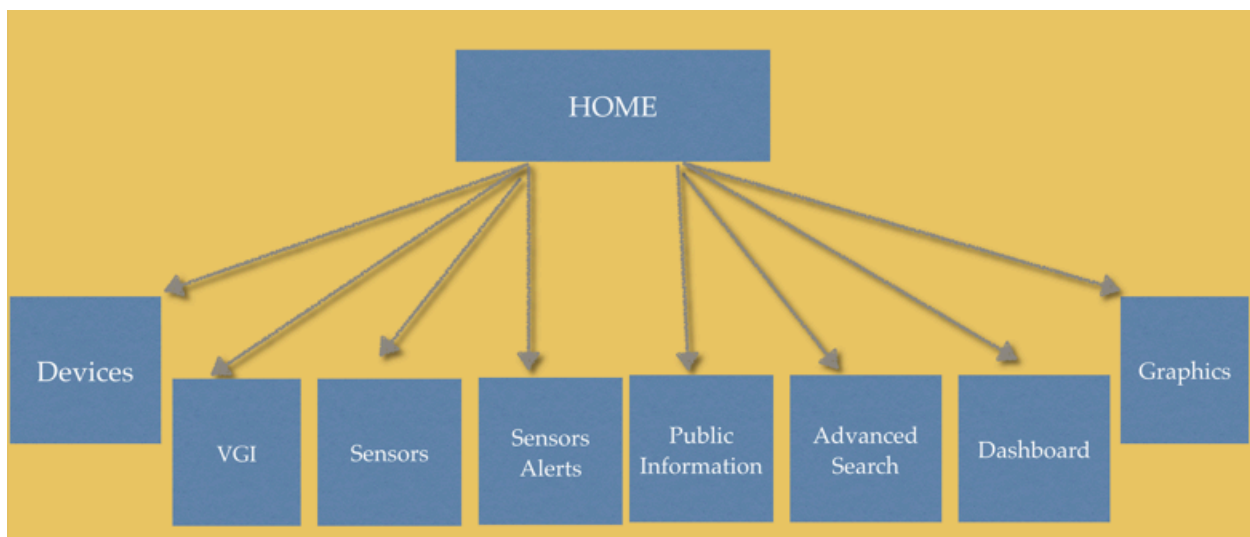


Figure 3: Main page structure

As can be seen in the image above, the main page has seven links that represent all functionalities that the website affords.

The link *Devices* connects the user with all devices around the campus and its facilities. The information is organized in such a way that the user will be able to easily find the device that he is looking for.

All devices in the map are represented in layers. There will only appear in the map devices of the same type. If the user selects the layer *Cameras*, it means that all the campus' cameras will be shown in the map.

In order to find a specific camera, the user has to click on the Advanced Search link to make possible the search for a specific location and a specific device's name.

The link *VGI*(Volunteer Geographic Information) represents the information coming from a mobile application. Through the mobile application, users will be informing the smart campus administrators about issues occurring on the campus. Users may report damaged properties, issues concerning to the IT department, hazards, roads and request room temperature or light changes.

Through this information that comes from volunteers, the main campus administrators can have control of all the campus and make decisions to fix proprieties and inform the community about the next steps to solve specific problems.

The link *Sensors* enables users to check the realtime sensors' data. The user can visualize the sensors' data in some specific location. It helps in decision making.

In addition, *Sensors alerts* represents all sensors according to a specific value of warning. All the sensors stablished as critical when the value exceeds some range, will appear as red in the map. On other hand, if the value is very close to the critical value, it will appear as yellow, informing that campus administrators they must be on alert. It helps at that moment to analyze and compare the information coming from users through VGI and the information coming from the sensors.

The link *Public Information* is the link that connects the campus administrators with all LCD screens on the campus. The campus administrators will be able to redirect a specific message to a specific screen or LCD on campus.

*Public Transportation* link is to verify in realtime the position of the bus in the map. The point representing the bus will be moving around the map.

The *Dashboard* link is a specific link for electrical management. In this link the smart campus administrators may cut the power supply to one specific building. In addition, main campus administrators will have the option to visualize the quantity of energy saved in the power plant and see the energy being sent from solar panels to the main power plant.

The link *Graphics* is mainly used to monitor sensors' values and solar panels' values in graphics in different ways. Charts and graphics are available in this link.

## **Buildings**

Buildings are just “.GLTF” files that are converted from “.DAE” format. The GLTF files are the files to represent a 3D building in Cesium. 3D buildings can be made in Blender, Google SketchUp, AutoCad, Maya and so on.

On the other hand, a JavaScript code used by GeoDjango does its job putting the 3D building in the right location in the map.

On the main page, buildings are clickable instead of only representing the 3D infrastructure. The user has the possibility of clicking on the building, choosing the floor, opening the room and picking the device to perform a specific task.



This sequence of steps was only possible to design and make available in the map because of the myriad resources that the Cesium library affords.

In the image bellow a demonstration of buildings resource is represented. The user is able to click on buildings and perform tasks.

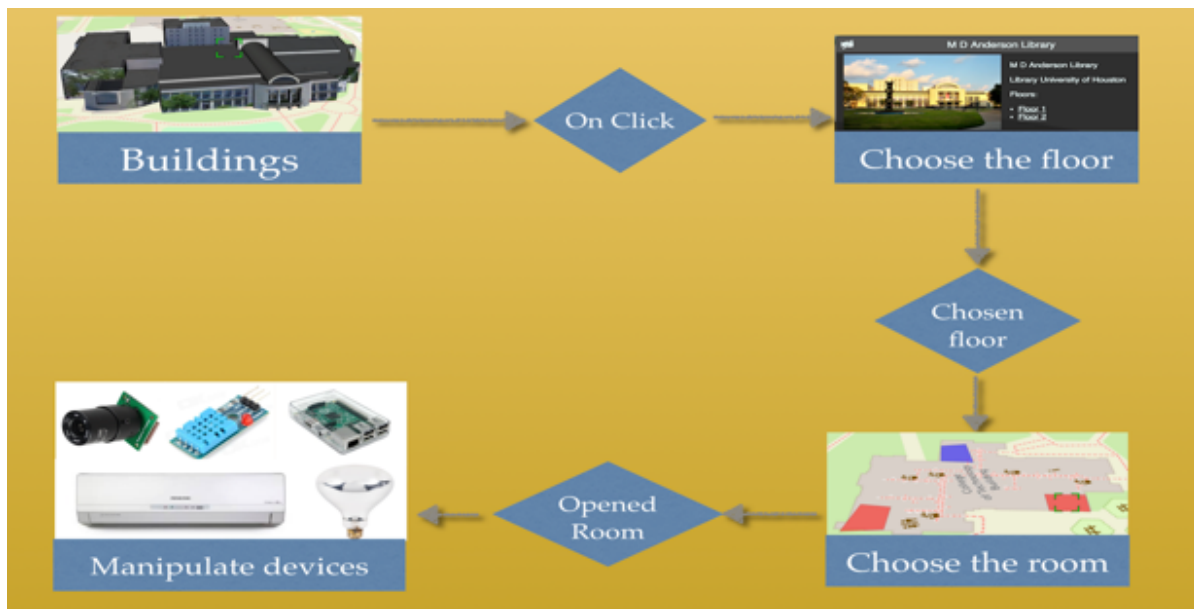


Figure 4: Building flow chart

## Devices

Smart devices deployed around the campus and facilities can be manipulated directly through the map. When the user clicks on the device, the map shows a menu for performing tasks.

If the clicked device is:

1. Raspberry pi: The user will have available a SHELL to access the selected computer through SSH.
2. Lamp: Users can increase and decrease the light intensity
3. Air Conditioning: The function for changing room temperatures will be available.
4. Sensor: The user can watch values in realtime
5. Solar Panel: Users can watch the quantity of energy being collected by the referred solar panel at a specific time.
6. Smart Door: Users can see the functionality of the object.
7. Camera: When the administrator access the camera, They can record a video, take pictures, change the configuration of the camera, as well as put the camera in motion mode detection and download videos previously captured by the camera.
8. Screens: Smart campus has screens for public information. Through the map, the administrators will be able to write a message to specific screen, in specific location.

The image bellow represents the flow chart of devices, mainly, the behavior of each device when clicked.

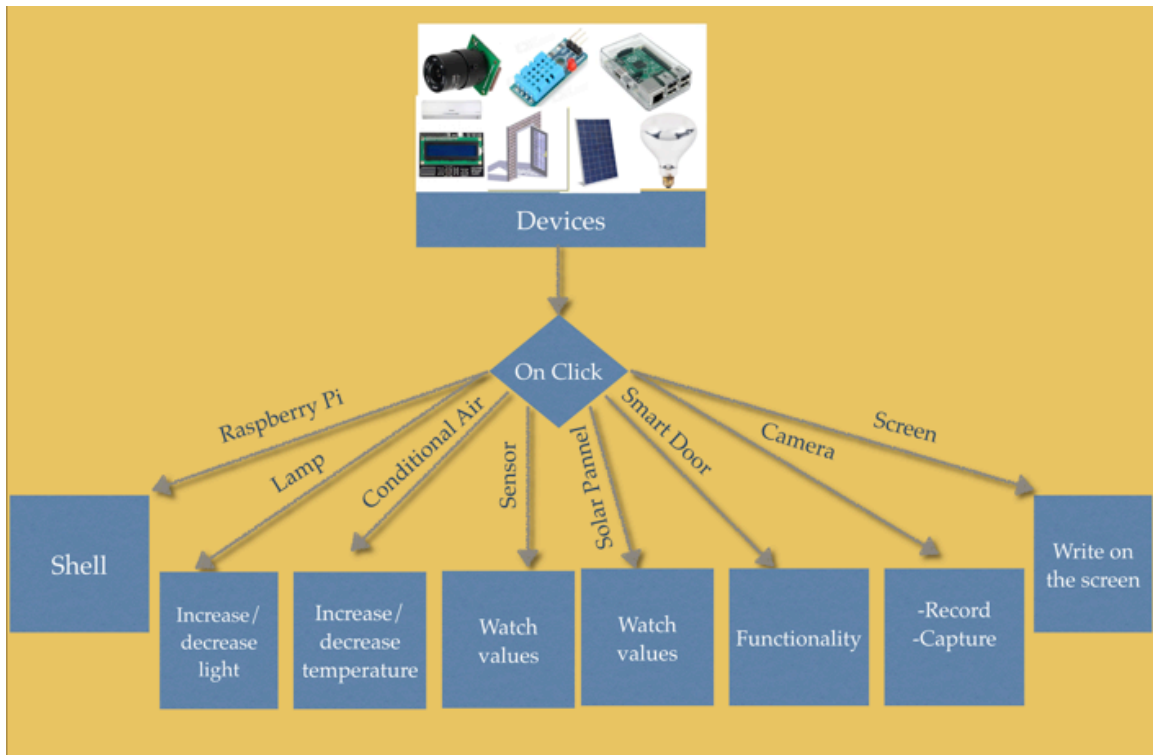


Figure 5: Devices flow chart

#### 4- Conclusion

Managing smart campus and its facilities has been a rough task nowadays, considering the number of smart devices that are present on the smart campus and facilities, as well as the amount of information and data that those smart devices are sending to the main station every second. WebGIS is a powerful tool for helping management, since it gives to the manager information and data geolocated and capabilities that the Internet has in terms of make the information accessible to everyone and everywhere in the world. WebGIS also can be integrated with mobile applications in order to communicate more simply with users and citizens.

## **Future work**

The main application can have a mobile application that helps users interact with the main campus administration and to notify administrators about ongoing issues on the campus. This application can have resources for taking picture about hazards, malfunctioning devices, roads and requests for temperature and lighting changes in some rooms, as well as to have access to sensors' data and public transportation.

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