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PROOF-OF-CONCEPT PROTOTYPING FOR OBSERVIS PLATFORM

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DESCRIPTION

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Abstract

Observis Oy is a start-up company first appeared in January 2011. The company is building up a measurement platform that is open and easy to connect. It helps measurement device suppliers, system and service providers, and analyzing services to found and combine each other’s products to create more value to the end customers. Observis Oy intends to develop a platform for integration with other services in order to provide management functionality in environmental field of business. Platform is expected to provide user-friendly way of presenting the data as well as comprehensive administration functionality. Service must be accessible directly from the cloud, implementing the idea of Software As a Service (SaaS) in its pure manner. Scalability must be considered as a key aspect, since integration of new devices and services must be done within limited time period.

The problem domain lays in the software development concept. Development team has been never experienced the technology before, resulting to a number of risks in that area. Because of the innovation nature of the platform, requirement became unclear; software design became more complex and unpredictable. Number of questions remains unanswered, such as interpretation of the existing spatial database scheme coming from 52°North company and decision on the most suitable programming language framework.

The goal of the project was a proof-of-concept prototyping for GEO informatics platform development. From the requirement specification and analysis of the future system and its expected functionality the general understanding was archived and converted into system design. Gained knowledge was immediately applied for implementing the most important parts of functionality in order to learn more about problem domain. Throughout the constant implementation, testing and changes of the requirements prototype was able to highlight the solution domain. Moreover, prototype has been used as on the presentation of the Observis Oy as a possible predecessor of Observis Platform.

Usage of the throw-away prototype methodology proved the ability to develop such a platform, defining boundaries, limitations and in-depth understanding of the solution domain. On the last development stage prototype reached the point, where it became suitable for promotion of the Observis Oy and discovered new exiting possibilities to study and research. Combination of the professional experience from Observis Oy development team and the knowledge of the newly released technology from MUAS’s practical trainee lead to the new dawn of the future leading Finnish company.

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CONTENTS

1 INTRODUCTION

For the past decades internet has experienced significant growth and impact of it to the society became more valuable than other social media. Openness, ease of use and accessibility of internet lead many people to be involved into developing and advertising goods as well as communicating with each other. As time went on, internet became a tool not only for personal discussions, but for making real deal as well. It all started at 6 August 1991, when the first web site was build at CERN (European Organization for Nuclear Research) becoming the oldest web site on the world.

Naturally, large business came to an idea of getting advantage from newly emerged area by presenting new types of business solutions. Those solutions required comprehensive development strategy and full understanding of problem domain as a combination of economical and technical skills. Key advantage over common product was the ability to provide service on demand, without wasting resources on something, which will not give back.

Meanwhile, society started to pay more attention to environmental impacts of power plants and ecology-related detection devices. Geographical structure moved towards information technology, resulting in number of consortium and development techniques creation. Spatial database schemes were introduced in form of stack-build on top of the regular database. Large influence was made in web area, such as SensorML and Sensor Web. GEO informatics became more popular, especially in countries with significant environmental presence.

In this thesis I will take a look at Software Engineering impact on environmental business idea development. Throughout the thesis I will introduce the theoretical foundation of enterprise development architecture, new influence of GEO-informatics, software engineering techniques and particular example of software development process, which was done in form of proof-of-concept prototyping serving as predecessor for Observis Platform.

The Observis Platform will consist of components, which will be responsible for gathering the measurement data, storing it in GIS database and providing a user friendly interface with maps and graphics, accessible via internet. Thus the aim of my study is to prove the feasibility of such system by developing a prototype.

1.1 Observis Oy

Observis Oy is a start-up Eastern Finnish company, located in Mikkeli. It started at the beginning of the 2011 year with solid experienced team members, who wanted to take a step into unknown field of environmental-oriented data retrieving and information processing. Company idea was to provide automatisation of customers business throughout all stages of operations as well as administrative functionality.

Target group of customers are environmental companies, needed a flexible, scalable, reliable and on demand accessible solution to manage and monitor their hardware equipment. Converting faceless data into presentable information flow was a key concept. Nevertheless, the system should keep itself up-to-date because new technologies and devices are popping out rapidly.

Problem domain of the customers consists of following things:

- Ability to add new measurement devices quickly
- Viewing and exporting statistic information
- Monitor the state of the measurement device
- Explore geographical locations and supporting information on the map
- Presenting information in user-friendly format (charts and tables)
- Process the information for analysis purpose
- Manage the existing devices

Business needs a tool to solve those issues. For that purpose Observis Platform has been defined as a possible solution. Developing such a platform from scratch could become a complex task, may be even impossible. Because of that, company decided to decompose problem into smaller pieces and start building a prototype, showing the solution for the most important parts. As time goes on, prototype will growth and cover more and more of the problem domain till it covers it all, turning itself into solution domain. After that exploration, company will be able to develop Observis Platform, based on the knowledge and requirements, gathered at the prototyping stages.

Success of the Observis Oy depends on that platform, since that it covers the target market of the company and remains the major innovative product compare to other companies.

1.2 52°North

52°North is a German R&D company form relatively small city of Münster, which happened to intersect the 52° degree latitude. That is really creative; every company should be named like that. The main area of operations is GEO informatics produced under open source licence and available to everyone.

Major development has been done in managing real-time sensor data, integrating GEO processing technologies into Satellite Digital Imaging System (SDIS) utilizing new macro trends, such as the Internet of Things and Semantic Web. Company is focusing on implementing the idea of Sensor Web, which is suitable for environmental monitoring.

Current products, developed by 52°North are as following:

- **SOS (Sensor Observation Service)** — provides access to sensor information (SensorML) and measured sensor observations
- **SAS (Sensor Alert Service)** — enables real-time alerting using a pub/sub paradigm
- **SES (Sensor Event Service)** — an enhancement and further development of the SAS
- **SPS (Sensor Planning Service)** — tasks sensors or sensor systems
- **WNS (Web Notification Service)** — supports asynchronous notification of sensor events

Also, they have developed a number of tools, supporting and making use of their products, such as OX-Framework and SWE Client (Sensor Web Enablement). Speaking about OX-Framework, it proved to be not suitable for Observis Platform; therefore I eliminated that tool and decided to have direct access to the core products.

2 ENTERPRISE TECHNOLOGY ARCHITECTURE

Enterprise technology architecture applies to high-scalable and heavy-load applications, operating with large amount of data. It’s mainly focus to fill the gap between pure IT and business needs providing more effective solution. In theory it can be distinguished by data-flow oriented, event-flow oriented or service-oriented. Taking companies needs into account, common cloud computing will be combined with some distinct aspect of the companies field of operation. For example, in my case such field will be a GIS which allows company to take the advantage of the geographical data manipulation within the internet. Enterprise applications usually are complex and consist of several subsystems, supporting the data interaction between them via interfaces and connectors.

2.1 Cloud Computing

Cloud computing brings a totally different way of delivering the software systems. It focuses more on the service rather than on actual piece of software, in other words it does not provide an access to the “physical” implementation of the product, but allows the usage of it. Cloud computing is also known as lightweight way of using old software via Internet. [4]

Cloud computing provides the same features as electricity, connecting together two unrelated fields. Both can be accessed from almost anywhere, both needs just to be plug in for operating, both does not require owing the product or generator station, instead they allow an access with monthly payment for usage. [4]

But what is inside of the cloud? It consists of several layers:

- Client
- Application
- Platform
- Infrastructure
- Server

Client is any device or application which gains the access to the cloud. Basically, client can be a web-browser supplied with variety of devices from mobile phones to laptops. [2]

Application refers to SaaS (Service as a Software) which delivers the service over the Internet on demand avoiding “physical” downloading and installing processes of application. [2] The application can be developed in form of a web-site on .NET or Java EE platforms, but emphasising on service rather than on web-content. Usually such tasks include either storing data in the database and its display or high speed computing over large amount of data. Among of all layers, SaaS or application layer is the most valuable in terms of software engineering, and therefore I will cover it in more details later.

Next step is a PaaS (Platform as a Service) which provides a solution stack for the upper layers. The world of PaaS divides between Windows-oriented and Linux-oriented solutions. Most commonly used are Linux-based systems, such as LAMP (Linux, Apache, MySQL, PHP), least popular alternatives are WINS (Windows, Internet Information Server, .NET, SQL Server). [2] Due to the higher prices, less flexibility and higher security risks WINS is used significantly less frequently than LAMP. However, it is possible and highly recommended to mix the parts of PaaS in order to archive specific business solutions. Developers are not forced to use only LAMP, PaaS can consist of any combinations, for example Linux as an operating system, Java EE as application framework, PostgreSQL as database and Apache or Jetty as application server. [2] It is possible due to the high level abstraction in server environment. There are much more abbreviations for the solution stack, but all of them service the same purpose — provide a platform for running services.

IaaS (Infrastructure as a Service) usually refers to virtualization of an operational environment instead of having real devices. [4] Sometimes, IaaS is called Hardware as a Service, which makes more sense. Business can use IaaS to outsource required equipment for installing PaaS and deploying SaaS on the top.

Server is literally a cloud-oriented hardware for supporting all the upper layers and providing accessibility from the client to the actual services. Server is not a virtualization, like IaaS, but a physical hardware with multi-core processors, while IaaS just imitates the operation of real devices. [4]

2.1.1 Software as a Service

SaaS has significant impact on the developing of new concepts for software engineering field. Previously, most of the applications were standalone and not able to communicate with each other. As the time goes on, communication protocols were developed to tight applications together, such as RPC (Remote Procedure Call) or SOAP (Simple Object Access Protocol), which despise of its name is not simple at all and lately was replaced by REST (Representational state transfer) which uses HTTP headers over the plaint XML files. Language-dependent libraries also emerged on the horizon, such as RMI (Remote Method Invocation) for Java allowing remote invoking of the function via the network. [2] Nowadays, services which are explicitly deployed on the server eliminate the need for build-in solutions inside of the standalone application so as the use of XML files either for mapping or declaration purposes. Because everything already lies in the network, it is more convenient to utilize communication methods, which are native to it, such as HTTP headers. Standalone applications can also benefit from this providing only the interface to the user, while all the computation processes will be called from the service. Such solution improves maintainability due to the fact, that application most likely does not have to be recompiled, therefore avoiding frequently updates. [4] Only the service has to be changed. On the other hand, if the client looses the internet connection, developed program becomes useless. Those are the prices for having centralized services with high maintainability and supportability, but also high dependency on the vendor. In reality, distributed systems are not that distributed if something goes wrong.

Typically, most of the companies offer SaaS for their customers and rely on outsourcing of PaaS and IaaS. However in case of gaining more independency and higher control all over the projects, company may purchase real server environment (or couple of servers, depending on the service load parameters), create virtualized environment on top of the servers, set up there their favourite operating system, application server for running the services and a number of framework or SDK's to support it. [2] Once it has been done, final step is to install suitable database (that is optional, but most likely it is essential to store some data rather than just compute mathematical equations). Client part it lays in the responsibility of the client himself, but the developed services which client access has to be developed by the company. SaaS part is probably the most flexible of all, because developers are free to choose almost any combination they need. [4] For example, .NET supports CLI (Command Line Interface) to allow usage of different high-level programming languages at the same time, meaning that company does not have to spent time and money to re-educate employees, instead it can have one department writing C# code, one for VB.NET and one for J#. [2] On the other hand, Java EE platform is less powerful in multi-language support, but still allows sending native calls to the functions inside of the foreign code using JNI (Java Native Interface), although it is cryptic and not recommended for common use. [2]

From the developers prospective, SaaS allows to archive [4]:

- High scalability, supportability, maintainability
- High control over the clients, especially on the payment options
- High risks of not providing the service due to high centralization
- Commonly provides an open interface for third-parties usage

SaaS is praised for having so called thin-client infrastructure, where service provider is considered to be fat. That brings the clients to following conclusions [4]:

- High dependency on the vendor and the network provider
- Data security cannot be guarantee by the company (privacy issue)
- Some services require access to services provided by another company (Amazon.com wants to be paid by Nordea Bank using credit card number and expiration date)
- Plug-N-Play capabilities of accessing the service

2.2 Geographic Information System

GEO informatics takes knowledge of geography and supplies it with informatics, resulting in the new engineering branch for managing the geographical data. Similarly, geospatial applies statistical analysis to the geographical data. OGC (Open Geospatial Consortium) is an international voluntary organisation, started in 1994 defines the GIS data processing and geospatial standards. [18]

GIS operates with four entities: feature of interest, procedure, observation and phenomena. None of them has precise meaning and they serve as a highly abstract definition for particular cases. For example, if the process defined as non-physical element, let say mathematical operation, then phenomena will become an input and output variable, while observation will serve as intermediate calculation result. [18] On the other hand, if user considers a process as physical element, let say space, then phenomena can be deformation of the space for input variables and density of the space as output variable, while observation will serve as snapshot of the space density phenomena, taken every minute. [18] As described above, all four entities may fulfill any developer needs.

2.2.1 Mercator Projection

GIS is highly dependent on the used projection for laying the spatial positions retrieved from the database. Coordinates for spatial systems can be represented in different projections. It is important to choose right one because otherwise all the markers and referred locations on the map will become offset from the expected position.

Commonly, maps are represented as rectangles with x-axis and y-axis for referencing to a specific square or a point on the map. When it comes to the map of the world, there is a problem — Earth is not flat. It might seem simple, but how does coordinates gets converted the ellipse-shaped Earth into the rectangle map. The same coordinates will be pointing at different squares on both of them, if units were not converted. Without falling in too many details, I will explain the major concepts related to such problem.

Theoretical foundation defines Mercator projection as a cylindrical map projection, which was developed by Belgian geographer and cartographer Gerardus Mercator in 1569. Google is using similar variation of such projection to as layout for GMaps. By default, GMaps is using Spherical Mercator, meaning that world is treated as a sphere rather than ellipsoid. The world known today is usually represented in Mercator projection between 82°S and 82°N, as it is shown on Figure 1.

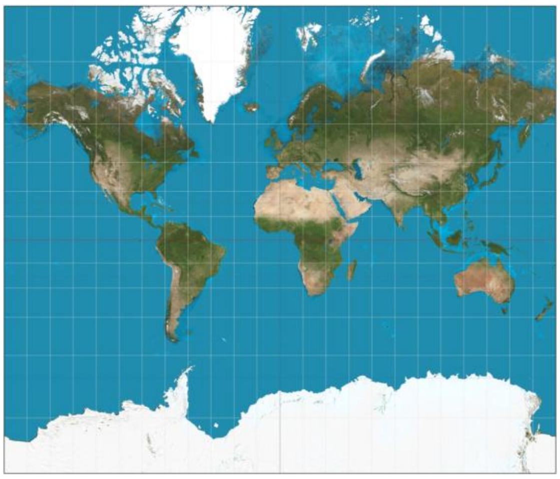


Figure 1: Mercator projection of the world between 82°S and 82°N. (US Government USGS)

Even thoughgh the Earth have cylindrical shape, parallels and meridians are associated in form of perpendicular to each other. Let’s agree **EPSG:4326 WGS 84** description as a standard in our case. Information from the spatial reference defines it as following [18]:

- **WGS84 Bounds**: -180.0000, -90.0000, 180.0000, 90.0000
- **Projected Bounds**: -180.0000, -90.0000, 180.0000, 90.0000
- **Scope**: Horizontal component of 3D system. Used by the GPS satellite navigation system and for NATO military geodetic surveying.
- **Area**: World

In case of using Pro4J library for converting from one projection to another usage of the following clause is required [18]:

```
+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs
```

OpenLayers, which is another JavaScript-based library, defines also world-as-a-sphere projection **EPSG:900913** as a base by ellipsoidal coordinates. **EPSG:900913** is used by web mapping and map visualization applications. [18] While **EPSG:4326** describes coordinates in form of latitude and longitude, **EPSG:900913** represents them as x and y. Those two projects are the most important and switching between them (recalculating latitude and longitude with x and y) is essential. Figure 2 shows the computing the Mercator projection from cylindrical.

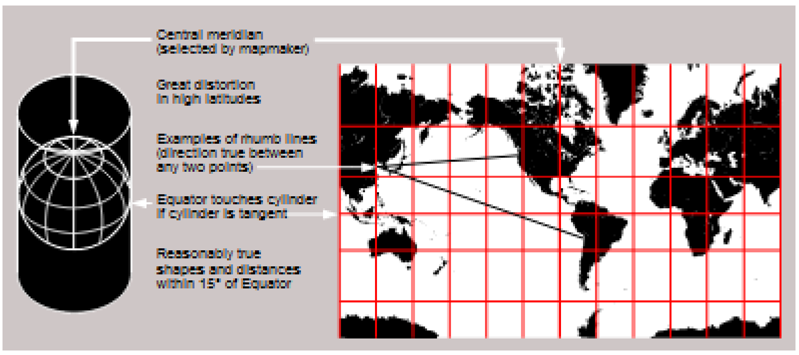

Central meridian (selected by mapmaker)
Great distortion in high latitudes
Examples of rhumb lines (direction true between any two points)
Equator touches cylinder if cylinder is tangent
Reasonably true shapes and distances within 15° of Equator

Figure 2: Computing the Mercator projection from cylindrical projection. (US Government USGS)

The point here is, most likely developers need to convert in between spherical representation of the world (also can be used traversal Mercator) and flat representation.

This is the most challenging things in software engineering, because developers are no-experts in every single field of science. Engineers deal with realistic problems, but they are not aware of "under the hood" concepts of projection, for example. Learning about new things is the part of our work, leading us to better understanding the world.

2.2.2 OpenLayers Structure

Like it was mentioned before, two important libraries to deal with spatial data are:

- **Pro4J** — supports large number of projections and converts values between of them

- **OpenLayers** — provide high-level abstraction for layout of the map, whether it is taken from Google, Yahoo, WMS or OpenStreetMaps. With OpenLayers it is even possible to attach your own maps supplied with boundary values so that coordinates of the real world will be applied to your particular map. Also, OpenLayers provide different kinds of operations with maps, such as laying Markers with Pop-up dialogs, drawing shapes on the map and determine whether marker is inside of the shape or outside.

Usually, Pro4J is used as an external add-on for OpenLayers. Let’s examine the basic structure of OpenLayers and discover how it communicates with third-parties frameworks and API’s.

Because OpenLayers is a pure JavaScript library, installing is fairly easy and comes down to including it inside of your HTML file:

```
<script type="text/javascript" src="./OpenLayers.js"></script>
```

Inside of the HTML file you need to specify the container for map. Important: it has to be a “<**div**>” clause, not “<**span**>”, otherwise GMaps will not display in certain browsers and OpenLayers also could experience problems:

```
<div id="map"></div>
```

Good practice is to specify width and height in external CSS file or under the style declaration. Here it is important, because otherwise map will be still displayed, but with width and height set to default value, which is 0, therefore you would not be able to see anything:

```
<style type="text/css"><!--
    #map {
        width: 1024px;
        height: 700px;
        border: 3px solid blue;
    }
--></style>
```

Next step is to define the time, when JavaScript, which I will create further, will be fired:

```
<body onload="init()">
```

Finally, I come to creation of a JavaScript code, which is the heart of OpenLayers implementation. Following example will create a map (Figure 3) in EPSG:4326 coordinate system with OpenStreetMap. Map will have one marker, which response with Pop-up dialog on mouse click: *[See Appendix 1 OpenLayers JavaScript with map and marker layout]*.

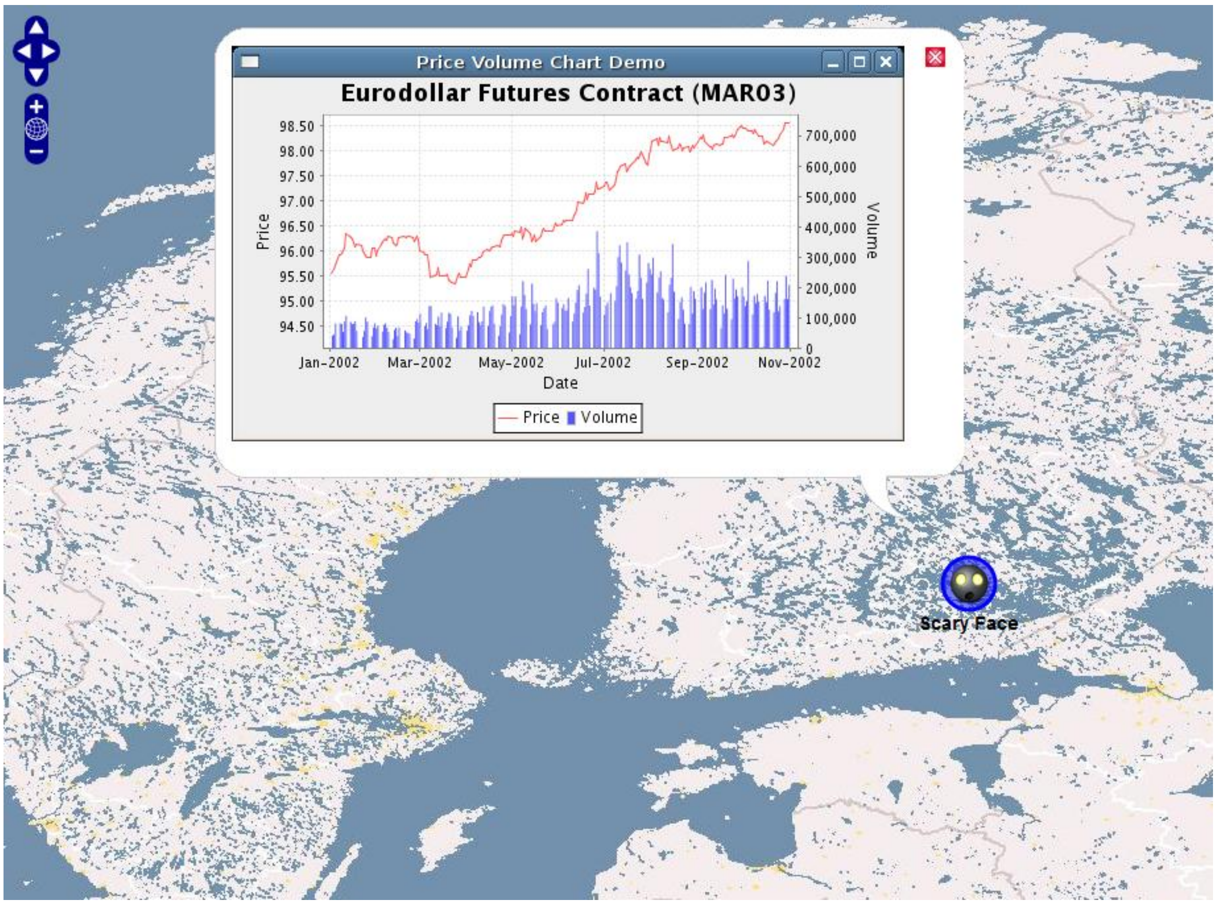


Figure 3: OpenLayers Map example of OpenStreetMap with Marker in Mikkeli.

As it was seen for the example, OpenLayers is very powerful and flexible library for operating with maps. Unfortunately, one of the drawbacks is the poor integration with back-end environment. I have experienced problems that not all the functions found their implementation in integration with Wickets Framework, even worst — it does not allow to customize or wrap the integration.

2.3 SensorML — Cleveland Volcano

The most important standard in our case is SensorML (Sensor Model Language). It provides an access to the process information (stationary and movable sensors, altitude, latitude and much more) in form of XML file. The process definition is very abstract and can be applied to many different things either physical or non-physical. In my prototype I will describe sensors via SensorML file and all the spatial manipulations with the database, markers, maps and logic will be dependent on it.

Major purpose of SensorML is to:

- provide sensor description, including its status and mobility
- provide sensor information for observation discovery
- provide sensor discovery
- perform on-demand processing
- specify input and output phenomenon

For example following SensorML file describes Cleveland Volcano located at fake easting 45, nothing 45, which is 1000 meters tall based on EPSG::4326 standard with operational status set to true having input parameters for time and output for ash and lava of numerical type: *[See Appendix 2 Cleveland Volcano SensorML description]*.

3 SOFTWARE DESIGN

Software engineering relies on design to provide the clear understanding of where component will be located and how they will communicate with each other. [4] The components themselves were taken from the requirement activity, but before they will be implemented, developers need to put some effort into design to archive the reusability, reliability, appropriate language-dependent patterns usage and maintainability of the future software product. [4]

3.1 Architectural Styles

In the design activity of software development process the decision on architectural style is critical. The way application behaves will set the rules for maintenance, extendibility, supportability and integration with other software components. The architectural style describes the basic intent of the inner structure of the software, revealing the main focus of such software. [4]

Choosing an appropriate architectural style is essential and when done wrongly it results in “Architectural Fault”, which is the most expensive and time consuming to repair. [4] Most of the time, architectural style is mistaken with software architectural — those are different terms related to the same field. Architectural style is a pattern for subsystem decomposition, while software architecture is an instance of architectural style. [4] Architectural style is not the same as software pattern either. The difference is same as with strategy and tactics, while style applies to application orientation, pattern defines a particular component structure, helping to archive the chosen style.

Architectural style relies on components and defines the best use of them. Components have to have loose coupling and high coherence in between each other to provide adequate realization for styles. [6]

There are many architectural styles in use, but I will concentrate only on the once, which are relative to the problem domain. Software engineers deal with complexity through modeling. [4] Following diagrams throughout this chapter assume the previous knowledge of UML diagrams. [7]

Architectural Styles can be split into three categories based on their intent [4]:

- **Communication** — Service-Oriented Architecture, Message Bus and Peer-to-Peer
- **Deployment** — 3-Tier (popular in Java EE Beans) and Client/Server
- **Structure** — Object-Oriented, Component-Based and Layered

In complex enterprise level systems it is common to see the usage of Hybrid Architecture, which combines different styles together. [6]

I believe Object-Oriented and Client/Server architectural styles needs no introduction; therefore let’s continue with less discovered techniques.

3.1.1 Layered Style

The system is split into several layers, communicating with each other via interfaces and sockets. Hierarchy of the layers is important, because a single layer is only aware of the lower layers (dependence on them), but has no knowledge of the higher layers. [4] Most commonly layers are represented in vertical top-down style. However, layers may consist of several partitions, located horizontally on the same level.

Because layers represent linear structure, there are only two types of relationship between them [4]:

- **Uses** — layer 1 has layer 2 (compile time dependency, represented in UML as association with solid line)
- **Calls** — layer 1 invokes functions of layer 2 (run time dependency, represented in UML as association with dashed line)

Partitions always call each other. Best practice is to have no more than one level relationship in both directions (top and down). Each layer can use or call only the lower layer. Figure 4 shows the layered architectural style.

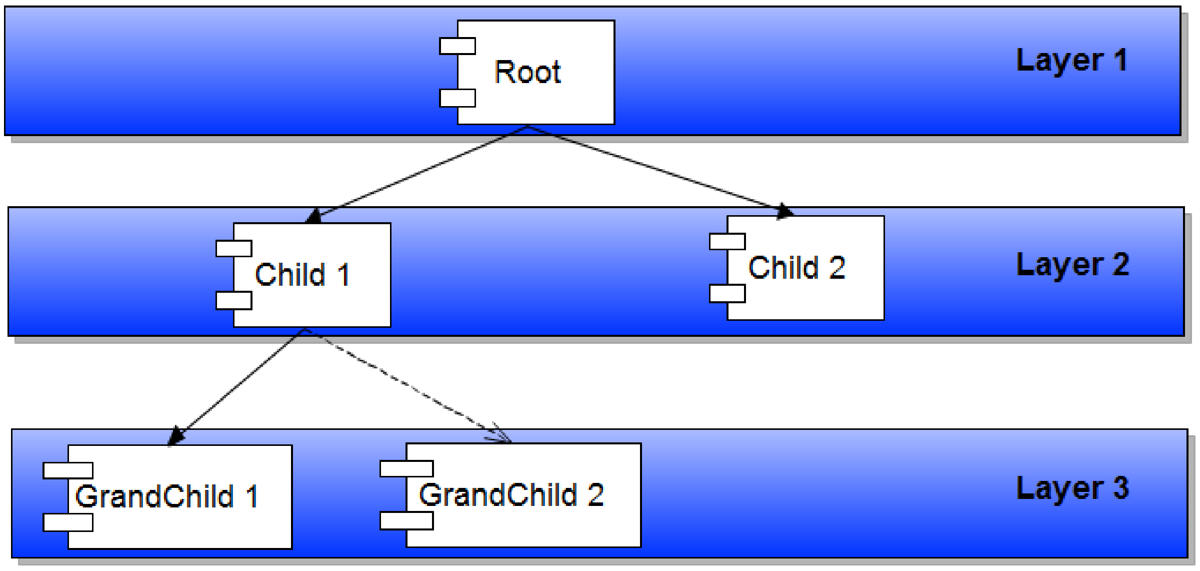


Figure 4: Layered Architectural Style.

Advantages of the layered architectural style [6]:

- Information hiding
- Reduce overall coupling, complexity, dependency, decompose system
- Easy to expand and replace one layer without modifying the other layers
- Layers can be reused in another systems

Disadvantages of the layered architectural style [6]:

- Degrade of performance due to the multiple passing of responsibilities

- Debugging the layers can be time consuming

Layer Style Architecture is the core concept and can be found in many other styles with different prospective. In the next part of this section I will concentrate more on the particular application of layer style architecture.

3.1.2 Multi-Tier Architecture

Multi-tier architecture relies on Layered architectural style, where single tier is an instance of a layer. [4] Reduced or minimal version of multi-tier is two-tier client/server style. There are two tiers, one for the client and another for the server, which may have following correlations:

- **Thin-client** — only the presentation layer is implemented on the client side, while all business logic and computations are passed to the server [4]
- **Fat-client** — all the business logic is implemented on the client side, so as presentation layer. Only database information is accessed from the server [4]

Best practice shows the benefit of the thin-client, because only the presentation of the model (reference to the MVC style) depends on the client archiving high level of control over client software/device. [6] For each type of client, whether it is mobile phone or browser, thin-client provides separate abstraction level. In perfect case, client must be limited only to the presentation, since that is the major dependency. None of the computation or logic, such as authentication or data retrieving should be presented on the client side. It allows having single service accessed by one or more clients. Major disadvantage, though, is that thin-client places heavy load on the network constantly passing data back and forth. [6]

Fat-client refers to heavy dependency on the client side, which is never a good thing. Imagine that service, existing on the core server environment of the company should be accessed in different applications. [4] Fat-client approach will lead to manual distribution of the components across all presentation levels. Fat-client puts fewer loads to the network, since all the computations are done on the client side, but also provides errors and inconsistency to the maintenance activity. [6] Delegating of the processes must be carefully planned before implementation.

Major advantage of thin-client over fat-client is absence of frequently updates to the client. [4] Multi-tier architecture extends from two layers to four at maximum. It is essential to keep the high of the tree around four or five, because higher number of layers will reduce the time accessibility, debugging and supportability due to the high passing iterations between the layers. However, multi-tier architecture is highly scalable and distributed in responsibility sense. [4]

For the past years the most commonly seen architecture was 3-tier, including presentation layer, business logic layer and database layer. In recent years architecture increased to 4-tier, separating application layer into data access layer (related to the database layer) and application layer (related to business logic and rules). [6] Usually, on the one end of the system there is a client, on the other end — database, and everything in the middle server as rule-based logic and data passing processing. The more complex system is the more layers it has to use.

Model-View-Controller (MVC) architectural style is usually confused with Multi-tier, therefore let's clarify the differences. MVC is non-hierarchical structure, which does not follow the pure layer rule of unawareness of the upper layers. [4] Instead, Model component can send notification to the view in order to update it. Multi-tire is hierarchical structure, which follows the rules of layer style, meaning that presentation layer never communicates directly to the database; instead all communication is done only between the one-order layers. [4] The lower decomposition goes (in direction to the database) the more similarities arise across the projects because data access is the same for most of the entities, the business logic is different and the presentation level may vary even within the same project. [6] I will discuss MVC in more details later.

3.1.2.1 Java Enterprise Edition

Multi-tier architecture became standard in Java EE framework in form of EJB (Enterprise Java Beans). There, Oracle is using 3-tier structure, where each layer is a file:

- **Entity** — is a class, which has explicit mapping to the database table, which is nothing more than class definition, no complex operations are required. Mapping can be done either via external xml or, most likely, via JPA (Java Persistence API) with @ annotations [10]
- **EJB** — serves as a wrapper for Entity, supplying it with basic CRUD (Create, Read, Update, Delete) operations dealing with database [2]

- **ManageBean** — only here the business logic makes its appearance, communicating with EJB object. Even though this layer is considered to be an end-point in Java EE structure, it's clearly not [2]
- **JSF (Java Server Faces)** — is a presentation layer for displaying controls and firing events to the ManageBean, which is usually explicitly annotated with particular JSF file. Also, instead of JSF file there could be a RESTful service allowing third-parties to utilize the system functionality. Actually, JSF relies on the request-driven MVC architecture [2]

To make things more clear, let's have quick example of minimal Java EE 3-tier architecture. All imports, getters and setters are omitted to save the space, also annotations are used as a best practice. Of course, in reality tables in the database are connected to each other, but here I want to emphasize on the tier structure, anyway such complexity can be held by annotations.

Development starts from the creation of a database (in our case it was MySQL, but it does not make any differences). Typically once developers get familiar with database structure, they create an entity, EJB and manage beans for them following the top-down approach from the database to the presentation layer. [2] Figure 4 shows the table schema for employee.

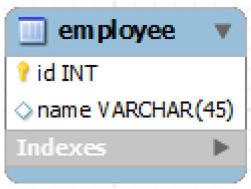


Figure 5: Employee Table.

Here I create a single table with id for primary key and name as a string attribute.

Table Employee

```
CREATE TABLE `employee` (
  `id` INT NOT NULL ,
  `name` VARCHAR(45) NULL ,
  PRIMARY KEY (`id`)
);
```

Now table has to be mapped with the entity using JPA annotations. Also, there are two prepared SQL statements for querying the data. Entity must always implement serializable interface in order to be passed via the network. [2]

Entity:

```
@Entity
@Table(name = "employee")
@NamedQueries({
    @NamedQuery(name = "Employee.findAll",
        query = "SELECT e FROM employee e"),
    @NamedQuery(name = "Employee.findById",
        query = "SELECT e FROM employee e WHERE e.id = :id")})
public class Employee implements Serializable {
    private static final long serialVersionUID = 1L;

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    @Column(name = "id")
    private Integer id;

    @Column(name = "name")
    private String name;
}
```

Next step is to provide a CRUD operation to our newly created entity using the entity manager, which is a part of Java EE platform. EJB's can be stateful, stateless or singleton, which literally describes its intent. [2] Stateful retain the state across multiple pages, Stateless dies as soon as user lives the page, Singleton implies a Singleton Pattern, ensuring that the only one instance of it exists across all the pages. [2] I have to mention that not all the frameworks support EJB annotations, for example Adobe Flex ignores the states and uses any EJB in stateless form. [13] Only add-on for Spring Framework can solve the issue, but this is outside of the EJB scope. [12] Also, EJB can use persistence context for accessing the database using a unit name, given in persistence.xml file. [2]

EJB:

```
@Stateful
public class EmployeeEJB {

        @PersistenceContext(unitName = "EmployeeEJB")
        private EntityManager em;
        public List<Employee> getEmployees() {
                TypedQuery<Employee> query =
                        em.createNamedQuery("Employee.findAll",
                                Employee.class);

                return query.getResultList();
        }

        public void updateEmployee(Employee employee) {
                em.merge(employee);
        }

        public void addEmployee(Employee employee) {
                em.persist(employee);
        }

        public void deleteEmployee(Integer employee) {
                TypedQuery<Employee> query =
                        em.createNamedQuery("Employee.findById",
                                Employee.class);
                query.setParameter("id", employee);

                em.remove(query.getSingleResult());
        }

}
```

After creating an EJB for managing the Entity class, developers can either create a manage bean and map it to the JSF, or create any controller class, which will take care of business logic. To simplify things, I will create a simple controller here.

Controller:

```
public class EmployeeController {
        private EmployeeEJB EmployeeEJB;
        private Employee Employee = new Employee();
        private List<Employee> EmployeeList = new ArrayList<Employee>();

        public void SetEJB() {
                try {
                        EmployeeEJB = (EmployeeEJB) new InitialContext().
                                lookup("java:global/EmployeeEJB");
                } catch (NamingException e) {
                        e.printStackTrace();
                }
        }

        public List<Employee> getEmployees() {
                this.SetEJB();
                setEmployeeList(EmployeeEJB.getEmployees());
                return getEmployeeList();
        }

        public void updateEmployee(Employee employee) {
                this.SetEJB();
                EmployeeEJB.updateEmployee(employee);
        }

        public Integer addEmployee(Employee employee) {
                this.SetEJB();
                return EmployeeEJB.addEmployee(employee);
        }

        public void deleteEmployee(Integer employee) {
                this.SetEJB();
                EmployeeEJB.deleteEmployee(employee);
        }

}
```

This way it was possible to create 3-tier structure with Entity, EJB and Controller layers.

Consider the example, where the system has two presentation layers for Adobe Flex and JSF files. System uses MySQL database and works on the Java EE technology for application layer, the particular framework is standard binding Entity/EJB/ManageBean, but for data access layer developers decided to use Hibernate. Apache Tomcat is used as an application server. For illustrating such case, let's examine the following deployment diagram (Figure 6).

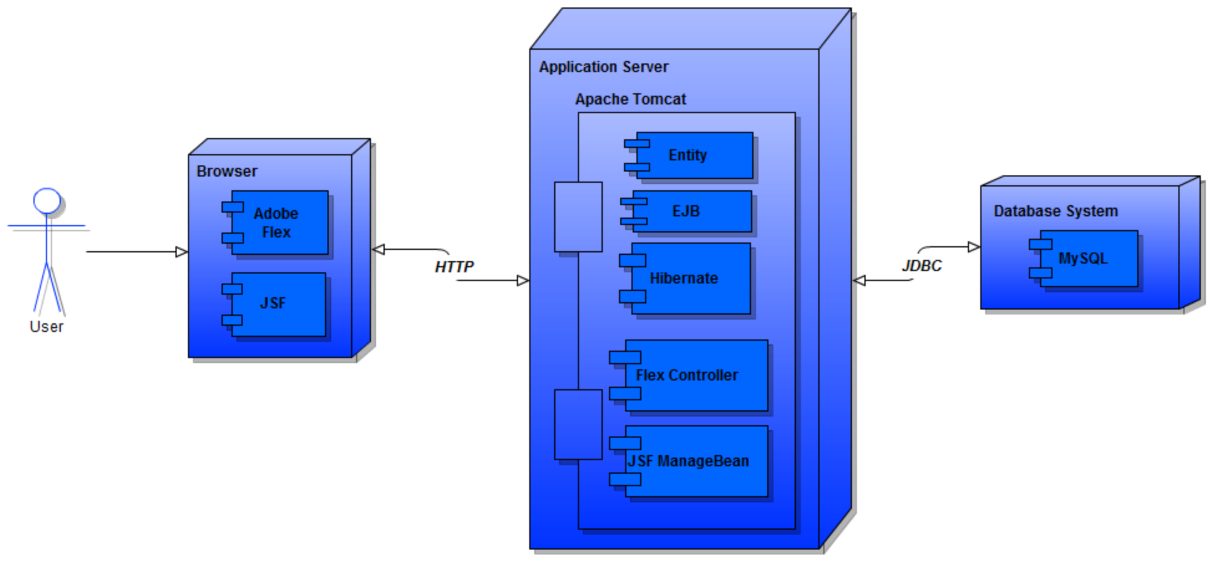


Figure 6: Deployment Diagram of Multi-tier Architecture.

It is hard to distinguish the data access layer from application, but I consider the Hibernate for data access and Entity as the representation for business logic class. In such case, the multi-tier structure will become as it is shown on Figure 7.

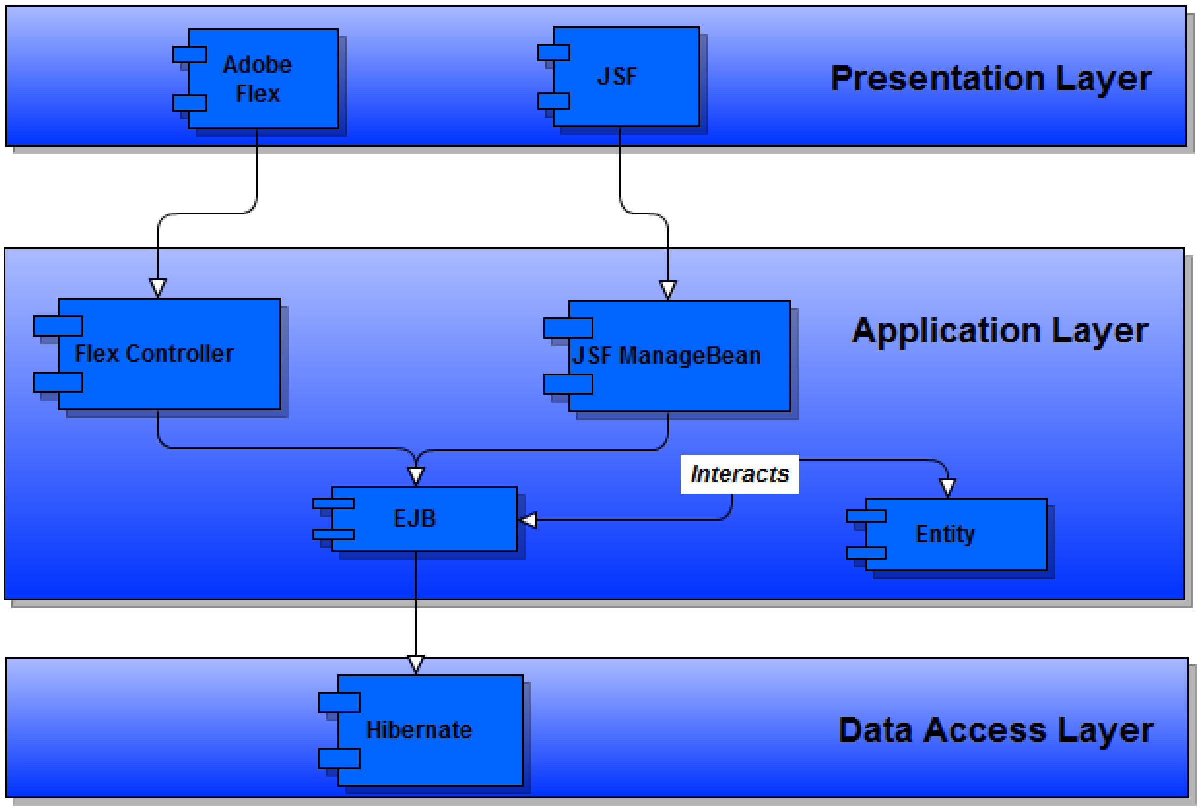


Figure 7: Breakdown of Multi-tier Architecture into layers.

I know that previous standard Java EE 5 received mostly negative review resulting into developing of many other frameworks, such Wickets, Spring, ICEfaces and much more. Nevertheless, new version Java EE 6 improved a lot from its predecessor and now is capably of many things, provided by the community frameworks. Last time I have been on the Java Tech Day conference I was impressed by time management beans and singleton EJB states as well as simplicity of layers and usage annotations over the xml files. Also, Ajax capabilities are now available under Java EE 6 version, defeating the major advantage of ICEfaces.

3.1.2.2 Presentation Layer

Nowadays, presentation layer mostly consist either of HTML, CSS and JavaScript combination or Adobe Flash components, bind to the controller on the server side. [2] In such sense, presentation level is usually called front-end, while the server side called back-end. In case of having HTML file for presentation, most likely developers will be using frameworks to create the GUI on the back-end side rather than code everything themselves. [4] It works in a way, that when application is compiled, components from back-end java are converted into their presentation with “id” attribute for referencing.

There are many approaches, for example GWT (GoogleWebToolkit) and its GXT (Sencha JavaScript project) extension compiles all java code into obfuscated version of JavaScript avoiding writing a single line of html. [14] [15] On the other hand, GWT also provides similar implementation of ManageBean and JSF if needed. The communication is done via RPC (Remote Procedure Call) form presentation layer to the back-end servlet. Even though application, developed with GWT, is highly functional (implements most of the windows-feel GUI by default, rather than emulating the HTML components) it is not flexible to configure and limited in custom design. [14]

Other frameworks (which are more common to find) are similar to JSF MVC structure, forcing developers to deal with not only HTML code, but also the specific extension to the html, such as for loops and if statements. The syntax and rules vary from framework to framework introducing high dependency and relations to the chosen framework, because programmers do not want to rewrite the entire presentation level (which is the largest among of all layers) due to the changes in architecture or deprecation of the framework.

Most likely, HTML pages will not be only supplied with nice graphics and CSS styles, but also with JavaScript, providing the distinctive user experience and increasing responsiveness of the application. Even further, for communication with back-end java, Ajax (Asynchronous JavaScript and XML) can be used, since pure JavaScript interacts only with the user. [1] Java EE 5 received most of the negative reviews due to the lack of Ajax integration, but wince Java EE 6 that issue has been completely solved. [2] Ajax is capable to send asynchronous signals to the back-end java, meaning that application can remain working while the request is processing. [1] Once it has been processed, Ajax receives response from the server and reflects to the user. Notice that that no page refreshing or page change required during those operations, decreasing the waiting time and increasing the productivity. Usually, Java-based frameworks comes with build-in Ajax library, but for those, who is still programming with PHP there are number of open-source Ajax libraries, such as Prototype JS and jQuery, for manual handling the requests. [1] However, in case of using both Wickets, which has build-in Ajax library and jQuery, which is an open source, jQuery turns out to be unable to send the request. [16] The problem is a security issue, because Wickets has secure URL paths by default and jQuery cannot predict the URL where it should send the request. [16] It might be different with other frameworks, but remember that integration has been always an issue with complex systems.

Some application requires the usage of advanced graphics. Providing the diagrams, flow charts and histograms impresses the user more, than pure data in table format. There are two alternatives: using flash-based charts (OpenFlashChart), static generated images (jFreeCharts) or dynamic interactive diagrams (jQuery based solutions). Obviously, user experience will be higher in case of interactive diagrams, but flash could also be considered as an option, especially in case of Adobe Flex, which has its own library for graphics. Users of GWT can benefit from external library GXT, which pre-renders the flash with supplied values from JavaScript. [13] [14] [15]

3.1.2.3 Application Logic Layer

Application layer provides the core implementation of the business requirements. This is the most variable layer among the projects, considering the constancy of presentation level. Unlike other layers, application mostly consists of POJOs (Plaint Old Java Object) and controllers to them, for example in Java EE 3-tier architecture it would have been a Controller, EJB and Entity classes. [2] EJB is an interface to an Entity, Even though Entity has database mapping. It depends, because if EJB is using Entity Manager, then it is talking to the database, but if the system uses Hibernate, then EJB is just a wrapper to an Entity. [2]

The form of application layer structure highly depends on the project and cannot be predict beforehand. It is necessary to distinguish the application layer from its relatives, such as data access and presentation. Application layer receives the notification from presentation layer, mainly caused by user actions (or triggered event from other services), process the data inside of itself, retrieving or storing some data to the data access layer if required. [4]

Application layer may also provide a service for other applications, for example in SOAP or RESTful formats. It also handles authentication and authorisation processes. Generally, this layer is non-language dependent, because logic can be created no matter what developer uses, either .NET or Java EE technologies. Besides the application layer, there could be other middle layers to handle the communication with different clients. [4]

Imagine that the system has two clients, one wish to use Adobe Flex application, another JSF, both exists as presentation layers. In order to handle the communication via BlazeDS channel developers create a controller (as it was done in the example), but this controller cannot be mapped with JSF page, because it requires a ManageBean. Therefore developer may enhance the application layers by middle-interaction for passing values back and forth.

3.1.2.4 Data Access Layer

Data Access layer only serves as an intermediate between application layer and the database and is very similar in its behaviour to EJB and Entity. [4] Usually that communication is done via mappings of the entity to the tables, but it does not have to be true for every system. [10]

Wicket does not maintain any particular ORM (Object Relational Mapping) or entity objects; therefore developers are forced to use third-party libraries, such as Hibernate, JPA and EJB for their POJOs. [17] On the other hand, Wicket provides a platform for simply web application development, eliminating the tight binding to the additional features, reducing overheat of the service and increasing flexibility of the application. [17]

Hibernate is in many ways similar to JPA, in fact JPA benefit from the last Hibernate release. It also provides two ways of mapping an entity to the tables: by xml-file and by annotations. However, it is recommended to use JPA annotations over Hibernate every time when it is possible, because JPA is a part of Java EE standard, while Hibernate is an open-source project, which may collapse in future. [10] [11]

Not often, but possible that some applications does not use database in common way. Considering the non-trivial databases, such as medical or spatial — there is now need to map the entity explicitly because the database provides an external service, which takes and sends xml files.

The reason for mapping at all is to wrap the object into tables for better use. The problem here is that Object-Oriented paradigm is a data-centric and event-driven, while database remains in the structural paradigm, which has been used one decade before. Structural approach was focusing on two techniques [9]:

- **DFD (Data Flow Diagram)** — for process modelling

- **ERD (Entity Relationship Diagram)** — for data modelling

Nowadays, DFD is not used any more in software production, but ERD is still used and Even though there was an intent to move towards object-oriented databases (which failed miserably), the ERD is used as a common structure for most of the databases. [4]

ERD structure is fairly simple:

- **Entity** — also known as a table
- **Relationship** — association between the tables
- **Attribute** — literally an attributes in the table

Meanwhile, programming technologies were developing and came to the object-oriented, where everything is represented as an object. But databases are still speaking structures. This is the time, when there is a need for an Adapter pattern, which the ORM is. It takes the object, annotate it with its inner variables providing loose-coupling and link them (each member variable) to the table (including all the associations between the tables). [11] Pure Adapter require no changes to the new or legacy system, however this does not apply to ORM. [4] XML-mapping files proved to be painful to maintain, therefore development moved to annotation, violating the rules of non-changes to the new system. [4] In such case, adapter merged with the developing system.

In software engineering field the biggest issue is to maintain the existing system. Database can be considered as an example of large scale problem. It is unclear what to do with it, because relation operations on the tables performs better with structural approach, which is not true at all in case of objects and programming languages. [9]

3.1.2.5 Wicket Framework

In the application I have developed Wicket Framework was used, which is a lightweight component-based web application framework, coming from Apache Software Foundation. [17] This framework and emphasize on simplicity of web-application, oriented only for data representation, assuming that all complexity will be delivered to the logic layer rather than web-site pages. [17]

As it was discovered above, it is possible to send the asynchronous requests to the server and receive the response on the client side. The types of data can be anything: JSON string, XML file as a string or object itself, implementing serialized interface (which also converts the object into string, but there is a need to de-serialize the object on the other side). Wickets has model based communication, which can associate a form, table, list view or any other GUI component with specific POJO and serialize it while processing back and forth. [16] [17] Everything in Wickets is a model, which comes handy while dealing with complex objects, their relations and constraints, although I do regret flexibility. Sometimes when you need to pass a single value, a string, it becomes impossible to do unless the wrapping a string into a model.

Each page in Wickets represented pair of .java and .html pages, explicitly bind by the name. [16] Such approach defines the manage class for HTML and adds the GUI components to the view. Let’s consider simple example of minimal Wicket application:

Wicket.html:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"
      xmlns:wicket="http://wicket.apache.org/dtds.data/
      wicket-xhtml1.5-strict.dtd" xml:lang="en" lang="en">
<body><div wicket:id="print"></div></body>
</html>
```

Wicket.java:

```
public class Wicket extends WebPage {
    public Wicket() {
        add(new Label("print", "Wicket to the rescue!"));
    }
}
```

WicketApplication.java:

```
public class WicketApplication extends WebApplication {
    public Class getHomePage() {
        return Wicket.class;
    }
}
```

The key thing here is an “wicket:id” attribute in HTML file. At the running time it simply gets replaced with the Label from components package with the same id as in the html. Of course Wicket supports many other features, such as html-inheritance, for loops, panels and components benefiting from Ajax technology, but I would like to give brief introduction here, and discuss the more specific examples in practical section.

Wicket supports many patterns, but one in particular is Observer. Wicket contains the list view component, which allows attaching or detaching the model and once the model has been changes — view changes as well.

The version, I was using, Wicket 1.5 did not have integration with jQuery library, and therefore I used a hybrid coding the JavaScript inside of the HTML file while providing the container id for the HTML blocks on the java side. Even though, newly released Wicket 1.6 do support jQuery in-core, the binding between both is the same, because JavaScript code has to be defined explicitly.

3.1.2.6 Relational Database Management System

Database is an organized collection of data, stored in digital format. [9] Most popular and effective way to store the data is to use relational database over object-oriented, simply because relational operations has less execution time. Also, it is more natural to represent data in relational format rather than object, because data retrieving is done over the large amount of data.

DBMS (Database Management System) defines the tables, their relationship, such as one-to-many, one-to-one and many-to-many (which is done via linkage table, both of which are one-to-many) and relational operations over them. [9] Operations are described in SQL (Structured Query Language) which is not fully compatible with relational algebra, but still widely used.

SQL is human-like programming language, which is fairly simple and obvious to use. Different databases tried to take advantage over standard SQL by enhancing it with their stored procedures and syntaxes, like PL/SQL for Oracle Database. [9] Relational database is highly coupled with SQL, but has different terminology for elements. [9] For example, relation is called a table, tuple is a row, and attribute is a column.

Main importance of tables is to be able to reference to the other tables. In relational databases it is done via primary key and foreign key. The primary key is only one for each table, but can be in compound form, so that it consists of more than one attribute. Primary key ensures the absence of duplicates in the relation, while foreign key in other table references to the primary key in first table, creating a link in between of them. [9] Link may have different behaviour, for example specifying “CASCADE” clause on certain operations (basically, delete or update) it may drop or update the child table, if parent has changed, introducing the consistency into database structure. [9] Tables are exist inside of the schema, but they still can reference to tables from different schemas, although SQL does not support it, therefore referencing is manual.

To reduce redundancy and avoid update anomalies normalization is taking place on the tables. First normal form is archived when table becomes a relation, meaning that there is no duplicate tuples. [9] Second normal form enhances the first one by moving partial dependencies to the external table. [9] Third normal form goes further in table decomposition to eliminate any functional dependency between candidate key and non-candidate key attributes. [9] The idea is so that in single relation will be no attribute which can identify the tuple, except the primary key. Best practice in database design defines that every table should be at least in third normal form. There are much more to decompose, Boyce-Codd normal form and up to fifth normal forms, but developers must keep in mind, that the more they decompose the tables, the longer retrieving operation will take due to the table joining. [9] Sometimes it is better to find optimal balance between the number of tables and redundancy elimination.

DBMS supports many other features, such as transactions for atomic operations, views, which are basically a view to the one or more tables, triggers and more.

To illustrate the table relations, let’s consider the university database with students, courses and university. All students belong to one university only, but the can be assigned for many courses, so as the course may have zero or more students. In such case, student will have one foreign key to reference to the university table, while assignment table will become a linkage to maintain the many-to-many relationship between student and courses, where primary key is compound and is the collection of its foreign keys. Relations are cascade in sense that if student or course gets deleted or updated, the assignment will reflect the changes and also gets either deleted or updated (updating means changing the primary key value).

Notice the normalisation, students and courses are not in the same table, because it will provide redundancy (each student will repeat the same course in its tuple) and inconsistency (updating one of the tuple with course name I will end up with the same course having different attribute values across the table). [9] Figure 8 demonstrates the database schema.

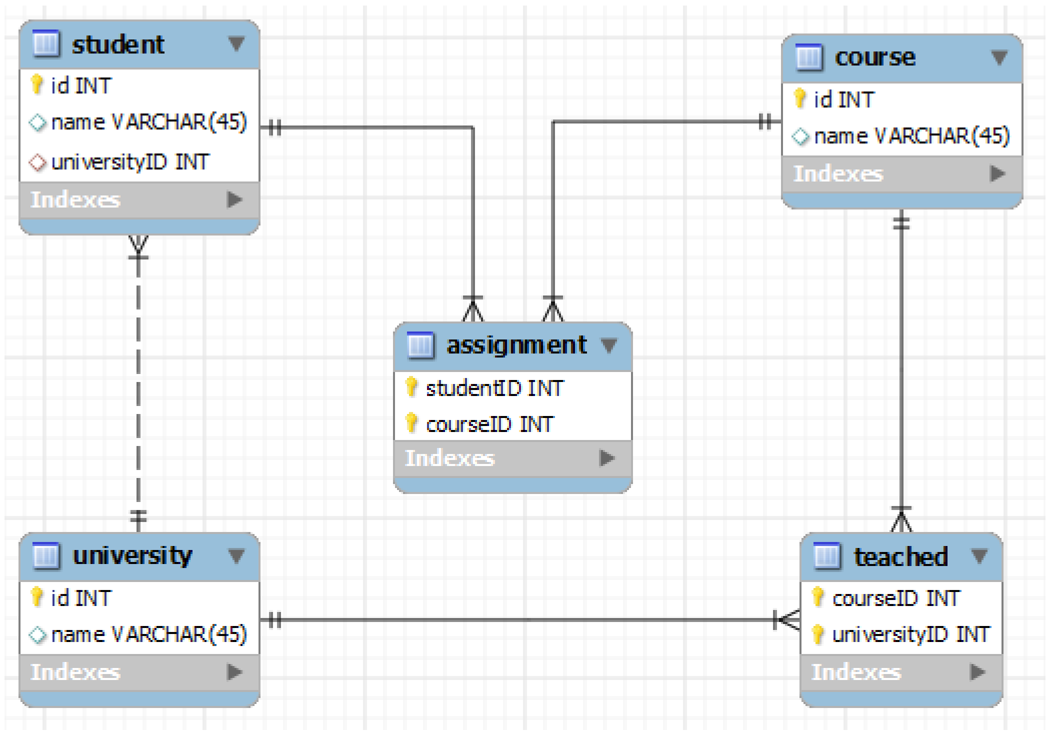


Figure 8: Database Schema for University Example.

SQL statements for creating such schema are as follows:

Database Schema:

```
CREATE SCHEMA IF NOT EXISTS `mydb` DEFAULT CHARACTER SET latin1 COLLATE
latin1_swedish_ci
```

University Table:

```
CREATE  TABLE IF NOT EXISTS `mydb`.`university` (
  `id` INT NOT NULL ,
  `name` VARCHAR(45) NULL ,
  PRIMARY KEY (`id`)
) ENGINE = InnoDB
```

Student Table:

```
CREATE  TABLE IF NOT EXISTS `mydb`.`student` (
  `id` INT NOT NULL ,
  `name` VARCHAR(45) NULL ,
  `universityID` INT NULL ,
  PRIMARY KEY (`id`) ,
  INDEX `universityID` (`universityID` ASC) ,
  CONSTRAINT `universityID`
    FOREIGN KEY (`universityID` )
    REFERENCES `mydb`.`university` (`id` )
    ON DELETE CASCADE
    ON UPDATE CASCADE
) ENGINE = InnoDB
```

Course Table:

```
CREATE  TABLE IF NOT EXISTS `mydb`.`course` (
  `id` INT NOT NULL ,
  `name` VARCHAR(45) NULL ,
  PRIMARY KEY (`id`)
) ENGINE = InnoDB
```

Teached Table:

```
CREATE  TABLE IF NOT EXISTS `mydb`.`teached` (
  `courseID` INT NOT NULL ,
  `universityID` INT NOT NULL ,
  PRIMARY KEY (`courseID`, `universityID`) ,
  INDEX `courseID` (`courseID` ASC) ,
  INDEX `universityID` (`universityID` ASC) ,
  CONSTRAINT `courseID`
    FOREIGN KEY (`courseID` )
    REFERENCES `mydb`.`course` (`id` )
    ON DELETE CASCADE
    ON UPDATE CASCADE,
  CONSTRAINT `universityID`
    FOREIGN KEY (`universityID` )
    REFERENCES `mydb`.`university` (`id` )
    ON DELETE CASCADE
    ON UPDATE CASCADE)
ENGINE = InnoDB
```

Assignment Table:

```
CREATE  TABLE IF NOT EXISTS `mydb`.`assignment` (
  `studentID` INT NOT NULL ,
  `courseID` INT NOT NULL ,
  PRIMARY KEY (`studentID`, `courseID`) ,
  INDEX `studentID` (`studentID` ASC) ,
  INDEX `courseID` (`courseID` ASC) ,
  CONSTRAINT `studentID`
    FOREIGN KEY (`studentID` )
    REFERENCES `mydb`.`student` (`id` )
    ON DELETE CASCADE
    ON UPDATE CASCADE,
  CONSTRAINT `courseID`
    FOREIGN KEY (`courseID` )
    REFERENCES `mydb`.`course` (`id` )
    ON DELETE CASCADE
    ON UPDATE CASCADE
) ENGINE = InnoDB
```

SQL for operation over the schema are as follows:

Register tens student to the MAMK university, which has id = 1:

```
INSERT INTO `student` VALUES (10, "Victor Ekimov", 1);
```

Retrieve the names of all the students from UWO university, which are taking the course named “DBMS”:

```
SELECT `student`.`name`
FROM `student`, `university`, `course`, `assignment`, `teached`
WHERE
`course`.`name` == "DBMS" AND
`university`.`name` == "UWO" AND
`student`.`universityID` == `university`.`id` AND
`student`.`id` == `assignment`.`studentID` AND
`teached`.`universityID` == `university`.`id` AND
`teached`.`courseID` == `course`.`id` AND
`course`.`id` == `assignment`.`courseID`;
```

Remove the course, from “LGU” university:

```
DELETE FROM `course`, `university`, `teached`
WHERE
`university`.`name` == "LGU" AND
`teached`.`universityID` == `university`.`id` AND
`teached`.`courseID` == `course`.`id`;
```

Change the name of all the students at “MAMK” university to “Matti”:

```
UPDATE `student`
SET `student`.`name` = "Matti"
WHERE
`student`.`universityID` == `university`.`id` AND
`university`.`name` == "MAMK";
```

3.1.2.7 Spatial Database Management System

Geometrical data are natural for spatial database. Besides the SQL queries, spatial databases can perform a wide range of spatial operations: [9]

- **Functions** — modifies the geometry with new one but of the same type
- **Measurements** — determine the distance in between two geometry objects
- **Predicates** — determine whether two geometry intersects, overlap or cross each other

Many databases, such as MySQL has add-ons to provide spatial operations. PostgreSQL database can be supplied with enhancing functionality to provide spatial capabilities. By using the stack builder, coming with the database, developers can install PostGIS stack, which enables the geographical data manipulations. For example, here is the list of documented functions, PostGIS can calculate:

- Distance(geometry, geometry) : number
- Equals(geometry, geometry) : boolean
- Disjoint(geometry, geometry) : boolean
- Intersects(geometry, geometry) : boolean
- Touches(geometry, geometry) : boolean
- Crosses(geometry, geometry) : boolean
- Overlaps(geometry, geometry) : boolean
- Contains(geometry, geometry) : boolean
- Length(geometry) : number
- Area(geometry) : number
- Centroid(geometry) : geometry

Here, geometry may be assumed as a point, line or a polygon. Therefore such operations as intersection of polygons, crossing lines, distance between two point are every-day operations for PostGIS and can be archived by enhanced SQL rather than calculating the data using the back-end programming language. Simplicity and task delegation serves for distribution of responsibilities among layers.

3.1.3 Model-View-Controller

MVC (Model-View-Component) style was developed to fulfil the needs of interaction with the user via GUI (Graphical User Interface). [4] The idea is to decompose the complexity of the system into three parts:

- **Model** — represents row objects for domain-specific information
- **View** — displays the model into user friendly interface (GUI), also view is bind to the model, in a way that if model has changed, the view gets updated as well (model sends notification and fires the update on the view side).
- **Controller** — handles the events, fired from the user or other external client in order to change the model

Figure 9 demonstrates the communication between components via calls and events.

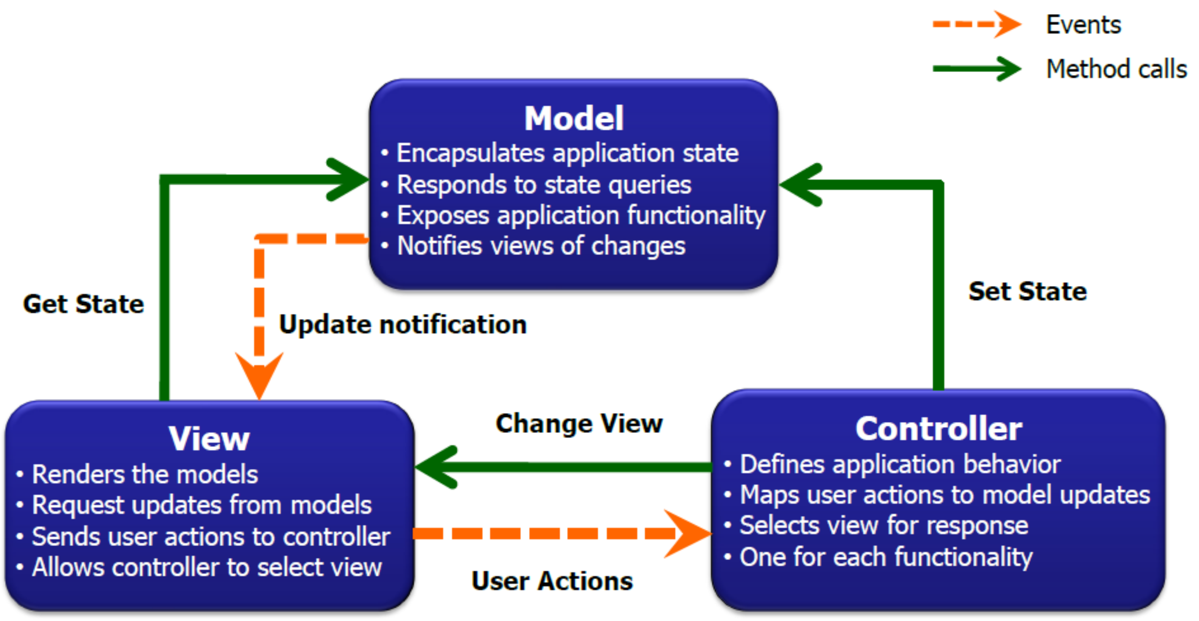

Events
Method calls
Model
• Encapsulates application state
• Responds to state queries
• Exposes application functionality
• Notifies views of changes
Get State
Update notification
Set State
View
• Renders the models
• Request updates from models
• Sends user actions to controller
• Allows controller to select view
Change View
User Actions
Controller
• Defines application behavior
• Maps user actions to model updates
• Selects view for response
• One for each functionality

Figure 9: Model-View-Controller Architectural Style. (Designing Enterprise Applications with the J2EE Platform)

MVC is one of the most popular architectural styles and it has been applied in large number of frameworks, such as Swing in Java, Adobe Flex, Wickets and Qt. [6]

Advantages of MVC [6]:

- Separates Data Access (Model), Data Presentation (View) and Data Transmission (Controller)
- One Model can be dynamically attached or detached to/from multiple Views and Controllers providing data centralization and reusability

Disadvantages of MVC [6]:

- Usually View and Controller are bind together and highly depend on each other
- Introduce complexity in debugging
- Reduce performance of GUI in case of frequent updates

In many ways, MVC relies on Observer Pattern, which will be discussed below, but MVC is not exactly an Observer, because it adds the presence of Controller. [4]

3.1.4 Service-Oriented Architecture

Service-oriented architecture provides well-understood communication interface for the third-party services or directly connected client (presentation layer). Such approach simplifies the web-development process and orient on the service usage, rather than language-oriented architectures. SOA (Service-Oriented Architecture) belongs to the set of event-driven structures, where the main motivation of it is to trigger the events and react on the changes, in contrast with structural set of orients, such as object-oriented architecture. [4]

Services are the end-points across the network and the way they communicate to each other has to be specified by the certain protocol. [4] Service-provider initiates the communication by serializing an object or to be more abstract — encoding the data, send it through the network till the service-consumer will de-serializing or decoded data, just like in the telecommunication transmission. [4]

Communication itself is done via network and is concern of network engineers, but what the developers are responsible for, is for defining the encoding/decoding format, obviously, if the sending format was JSON string and the receiver service expects XML, they would not be able to understand each other Even though the data were passed perfectly. [6]

Services implies the loose coupling in sense that services has very little dependency on each other, instead they use middle-layer (compare to Mediator Pattern) for data passing. [4] On service fires the event on the other service without direct binding in between. Previous implementations of standalone applications communicate via RMI in java, which was exceptional at that time, but with services the communication takes the major focus, and the objects are now used only as business logic representation. [4]

SOA holds on the principals of reusing the services in different projects (in matrix structure rather than linear), modularity, interoperability (ability of different services to work together) and granularity (system breakdown to smaller parts). [4] Service discovery is essential key, allowing the communication between services developed by different companies. For example, company may decide to provide RESTful interface for group of users to query the data, excluding the modification of it.

Two common formats, besides the manual serialization of the object are:

- **XML** (Extensible Markup Language) — markup language (with text annotations) identifies itself as comprehensive encoding document format, which is both human- and machine-readable. Example of xml was introduced earlier in the section “Cleveland Volcano”. XML are heavy weight documents, being way too precise than necessary they create overheat to the network and overcomplicate the development in case of requiring a simple data to be send. Also, XML files are used as configuration files because of its loose coupling nature, sometimes being wrapped with GUI
- **JSON** (JavaScript Object Notation) — lightweight pure text-based formats, which is also human- and machine-readable. Historically, it was derived from JavaScript language, as the name says, but other languages also may understand such format in case of having interpreter. [1] JSON structure is fairly simple and holds on Composite Pattern, which is has tree-hierarchy, where each child has itself (recursively) and/or leaf nodes. [4] Applying that, JSON either have a data (object, boolean, string or number) or an array, containing data or another array:

```
{
  "folder":
  [
    {
      "id": 1,
      "title": "first favorite file"
    },
    {
      "id": 2,
      "title": "second favorite file"
    }
  ]
}
```

Both JSON and XML may found its use in different parts of project, while XML is fully-functional suits the needs of complex systems; JSON is used in fast and simple data transmission.

Even though SOA can operate independently of communication technology, most of the projects come down to usage of following:

- **SOAP** (Simple Object Access Protocol) — highly depends on XML and basically enhance it with additional clauses for passing through the network [2]
- **RESTful** (Representational state transfer) — uses Uniform Resource Identifiers (URIs) for referencing to the resources in HTTP (Hypertext Transfer Protocol) methods, such as GET, PUT, POST, or DELETE. [2] Each method finds its literal implementation under certain object, which becomes really easy to implement using Java EE notations

SOAP consists of Envelope section, which includes Header and Body sections. Communication is done in a way that one service sends the SOAP-request to invoke the functions on the other service and waits for SOAP-response. However, Header section is usually omitted in simple non- authenticated communication. Consider the example of querying the name of the student by the student id number.

SOAP-Request: Student.xml:

```
POST /Student HTTP/1.1
Host: www.mamk.fi
Content-Type: application/soap+xml; charset=utf-8
Content-Length: XXX
SOAPAction: "http://www.w3.org/2003/05/soap-envelope"

<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope">
```

```
  <soap:Body xmlns:s="http://www.mamk.fi/students">
    <s:GetStudentRequest>
      <s:Id>250655695</s:Id>
    </s:GetStudentRequest>
  </soap:Body>

</soap:Envelope>
```

SOAP-Response: Student.xml:

```
HTTP/1.1 200 OK
Content-Type: application/soap+xml; charset=utf-8
Content-Length: XXX

<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope">

  <soap:Body xmlns:s="http://www.mamk.fi/students">
    <s:GetStudentResponse>
      <s:Name>Victor Ekimov</s:Name>
    </s:GetStudentResponse>
  </soap:Body>

</soap:Envelope>
```

SOAP is flexible and multipurpose standard, which can be used outside of the SOA, or can be passed through the firewall or proxy without any modifications. On the other hand, non-standardized RESTful technology overcomes the SOAP by simplicity, transfer speed and network-oriented structure.

In RESTful web service link is considered to be an object, while HTTP methods applied to it becomes an actions. Considering the link **http://www.mamk.fi/students/victor.ekimov**, methods can be assumed as following operations:

- **GET** — retrieve the information of the student
- **PUT** — update the student information, if student does not exist — create it
- **POST** — create a new student
- **DELETE** — delete an old student

Java EE technology has significant support of RESTful message passing, including the JAX-RS, which supports automatic creation of XML/JSON strings. [2] It is done via JAXB (Java

Architecture for XML Binding), which basically annotates the class with one or more xml clauses (for example, @XmlRootElement). [10]

To clarify the usage of RESTful technology and prove its easiness, let's examine the small Java system, which has JAXB for class with student id and student name, operating under JAX-RS. [10] Our assumption is that there is a Singleton StudenList, taking care of database-related operation at data access layer. The student class will be processed as XML having id and name fields as is:

RESTful: Student.java:

```
@XmlRootElement
public class Student {
        private int id;
        private String name;

        public Student(int id, String name) {
                this.id = id;
                this.name = name;
        }

        public String getId() {
                return id;
        }

        public void setId(int id) {
                this.id = id;
        }

        public String getName() {
                return name;
        }

        public void setName(String name) {
                this.name = name;
        }
}
```

RESTful: StudentRS.java:

```
@Path("/students")
public class StudentRS {
        StudentList studentList = new StudentList.getInstance();

        @GET
        @Path("{id}")
        @Produces("application/xml")
        public Student getStudent(@PathParm("id") int id) {
                return studentList().getStudent(id);
        }

        @UPDATE
        @Path("{id}")
        @Consumes("application/x-www-form-urlencoded")
        public void updateStudent(@PathParm("id") int id,
                                @FormParam("name") String name) {
                Sturent student = studentList().getStudent(id);

                if (student)
                        student.setName(name);
                        studentList.updateStudent(student);
                else
                        studentList.insertStudent(new Student(id, name));
        }

        @POST
        @Consumes("application/x-www-form-urlencoded")
        public void postStudent(@FormParam("id") int id,
                                @FormParam("name") String name) {
                studentList.insertStudent(new Student(id, name));
        }

        @DELETE
        @Path("{id}")
        public void deleteStudent(@PathParam("id") int id) {
                studentList().deleteStudent(id);
        }
}
```

In contrast with universal approaches, consider the BlazeDS channel for communicating between front-end Adobe Flex and back-end Java EE, where the message passing is binary by its nature therefore happens much faster, eliminating the need of encoding and decoding. [13]

Mainstream is currently moving towards the RESTful due to its simplicity and nativity to the networks, while SOAP remains an ugly shape monster resembling the old days of XML communication between standalone applications. For example, Google introduced RESTful API for its search engine in April 2008, discarding the SOAP API, which was introduced in December 2006. [14]

3.2 Software Patterns

The intent of patterns is to fill the gap between the System Design and the Object Design. At this point, developers realized the architectural style and classes they need to implement. Patterns will tight those two entities together via interfaces and sockets. [4]

While architectural style deals with components, software patterns describe the communication between classes using object-oriented paradigm. [4] Off-the-shelf components need to be connected with refined classes, realized as a business model. It is done through the Object-Oriented techniques, such as association, inheritance and implementation. [4]

Outsourcing of the commercial existing patters can result into 0% coding, but be less flexible and more expensive, especially considering the fact that all patterns can be developed by the company itself. [6] Usually, that is the case due to the specific requirement, not covered by the commercial patterns. This is not the case with STL (Standard Template Library) for example where it is strongly suggested to use their data structure and algorithms rather than developing your own. STL is multi-purpose and perfectly performs its intent, while the patterns have problem-oriented approach.

Software Patterns idea cannot be described better, than Christopher Alexander said in his book: *"Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice*". [19]

Alexander was talking about patterns in buildings, but software engineering has lot of similarities to the architecture, Even thoughgh it is done in the world of “virtual reality”. A perfect example of reuse the ideas across two engineering field was taken very serious into consideration by software engineers. Indeed, most of the problems arise at the design activity repeats from project to project making developers think about creating a ready-made component to handle such problems.

To understand the patterns communication it is necessary to differentiate association from inheritance and implementation. Association uses the instantiated class inside of itself, while inheritance literally inherits all the functionality from the parent class. The dependency of inherited object is higher, than of associated, because if the parent object changes its functionality, it will also change the behaviour of all the children. A perfect example will be discussed in the first and most commonly used pattern — Adapter.

There are many patters appeared in different books and projects, but most of them can be split into following sections based on their intent [4]:

- **Creational** — emphasize on the creation of the pattern, effecting the structure at the creation stage, such as Factory Builder and Prototype
- **Behavioural** — emphasize on the behaviour of the pattern, usually connected with user actions and communication between components, such as Chain of Responsibility, Command, Iterator, State, Strategy and Memento
- **Structural** — emphasize on the structure of the pattern, referring to the solid composition of the classes and their relations, similar to the behavioural, but does not depend on the event. Examples are Bridge, Composite, Decorator and Flyweight

In the rest of the section I will go through the patterns, which are relevant to the thesis. All examples are supplied with Java-style code and class diagrams.

3.2.1 Adapter

Some of the time, developers already have a component, which does certain operations in their repository, but the socket of it does not fit the interface of the developing component.

Motivation behind Adapted is to reuse the component, by converting interface of the new system into interface of the legacy system. [6] This way, both new and legacy systems do not need to be modified.

Consider the following structure: a client uses the NewSystem interface via Adapter class, which eliminates the incompatibility of doExecute() function. Notice, that client wants to pass two parameters (x and y) and receive void as the return type, but legacy system wants to accept three parameters, where x and y are switched, also it returns an integer, which client has no concern about. Also, LegacySystem has different name for the function.

This is the moment to divide association from inheritance. Notice that the Adapter inherits (implements) the NewSystem functionality. However the LegacySystem has its presents in Adapter class only in form of association. This is done, due to the maintainability issues, imagine that NewSystem extends as time goes on, but LegacySystem remains the same. Adapter automatically inherits (implements) all new function, but has the right to decide whether to use LegacySystem code or not, if yes — in what way. Figure 10 shows the Adapter pattern.

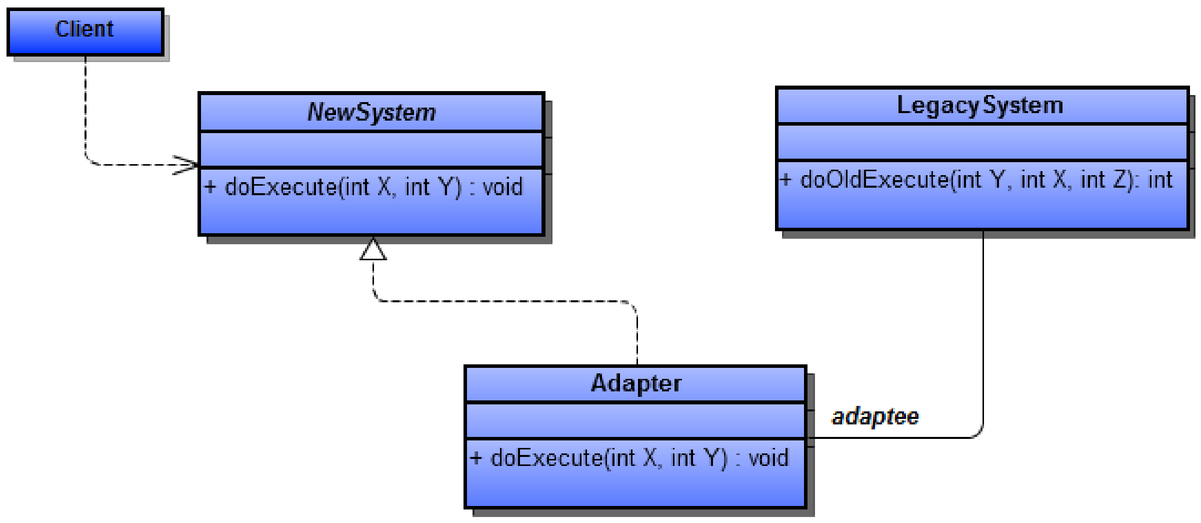

Client
NewSystem
+ doExecute(int X, int Y) : void
LegacySystem
+ doOldExecute(int Y, int X, int Z): int
Adapter
+ doExecute(int X, int Y) : void
adaptee

Figure 10: Adapter Pattern.

Imagine that all what is needed from the LegacySystem is to print out its parameters. Of course in reality it is more complicated, but the idea is the same, wrap around legacy code.

Client:

```
public class Client {
        public static void main(String[] args) {
                NewSystem adapter = new Adapter();
                adapter.doExecute(10, 20);
        }
}
```

NewSystem:

```
interface NewSystem {
        void doExecute(int x, int y);
}
```

Adapter:

```
class Adapter implements NewSystem {
        private LegacySystem adaptee = new LegacySystem();

        public void doExecute(int x, int y) {
                adaptee.doOldExecute(y, x, x + y);
        }
}
```

LegacySystem:

```
class LegacySystem {
        public int doOldExecute(int y, int x, int z) {
                System.out.println("doOldExecute(int " + y +
                        ", int " + x + ", int " + z + ")");
                return y * x * z;
        }
}
```

3.2.2 Facade

Facade serves similar purpose as Adapter, but rather than connecting two systems together, Facade provides a unified interface to the multiple subsystems. [6] That interface can even be separated based on the client type. In some sense, Facade brings new layers into the system allowing authorization and decision control all over it. Also, it shields the client from accessing inner classes, archiving information hiding and high level of security. At the same time, Facade does not prevent the client from usage of the hidden classes because all communication is done via aggregation. [6]

Consider the following example: clients A, B and C want to assemble the car. Calling each function from three different classes every time leads to inconsistency and errors in future development. Therefore, I create a Facade which has a single function to call, which will explicitly call all the required functions from the other classes. It also may act as a firewall, preventing the client C from accessing certain functions. Figure 11 shows the Facade pattern.

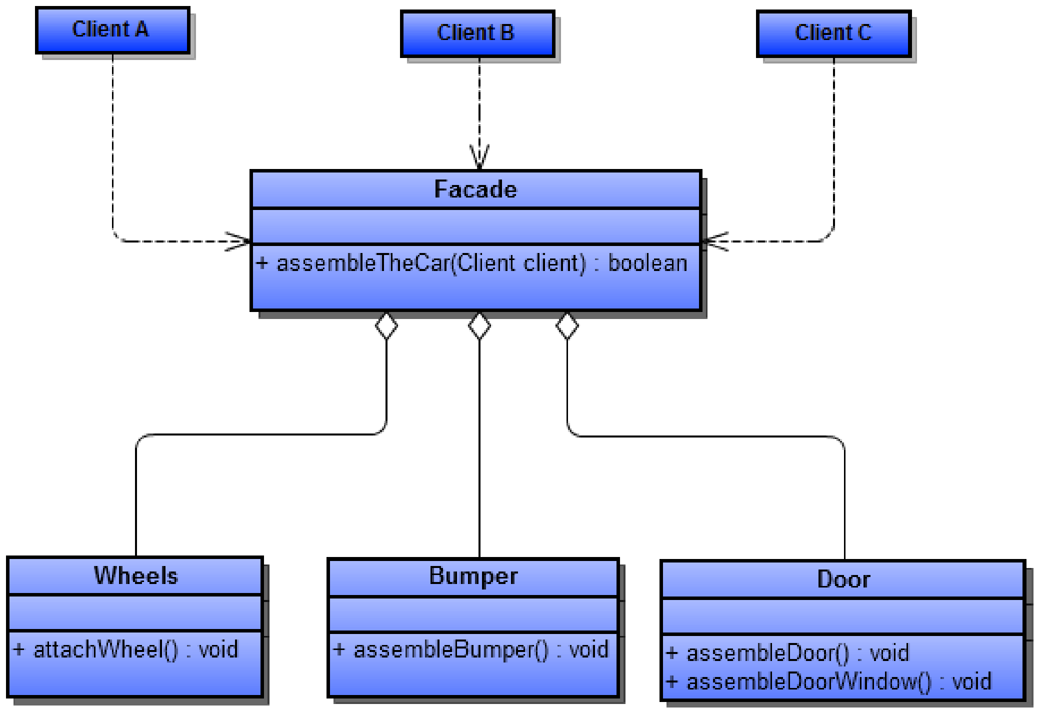

Client A
Client B
Client C
Facade
+ assembleTheCar(Client client) : boolean
Wheels
+ attachWheel() : void
Bumper
+ assembleBumper() : void
Door
+ assembleDoor() : void
+ assembleDoorWindow() : void

Figure 11: Facade Pattern.

Let's consider following code for Facade class. Inner classes' code is omitted due to its simplicity, here it would have been writing the parameters, but in reality it can perform whatever action it should. Our assumption is that client C did not pay for the car at all, while client B paid only for wheels. Also, clients have inner function, which check whether he paid or not for certain parts. It could be archived either of checking the instance of the object, or some values of the attributes.

Client:

```
public class Client {
	public static void main(String[] args) {
		ClientA clientA = new ClientA();
		ClientB clientb = new ClientB();
		ClientC clientC = new ClientC();

		Facade façade = new Facade();
		facade.assembleTheCar(clientA);
		facade.assembleTheCar(clientB);
		facade.assembleTheCar(clientC);
	}
}
```

Facade:

```
class Facade {
        private Wheels wheels = new Wheels();
        private Bumper bumper = new Bumper();
        private Door door = new Door();
        private Car car;

        public Car assembleTheCar(Client client) {
                car = new Car();

                if (client.paid(wheels)) {
                        car.attach(wheels.attachWheel());
                } else return Null;

                if (client.paid(bumper)) {
                        car.attach(bumper.assembleBumper());
                } else return Null;

                if (client.paid(door)) {
                        car.attach(door.assembleDoor());
                        car.attach(door.assembleDoorWindow());
                } else return Null;

                return car;
        }
}
```

3.2.3 Proxy

Proxy pattern is represented as additional layer between the system and object it wants to use. Sometimes it is necessary to provide security, filter options or sample view of an object, which is expensive in terms of performance (large image, video stream, large amount of data from database). [6] Avoiding the creation of the object at the start-up time archives the on-demand effect. [6] Although, object can be instantiated directly, not taking Proxy into account, it is a good practice to use two layer structure.

Notice that both of the classes inherits (implements) the Video interface. Essentially, both of them has the same purpose, but with slight difference. Figure 12 shows the Proxy pattern.

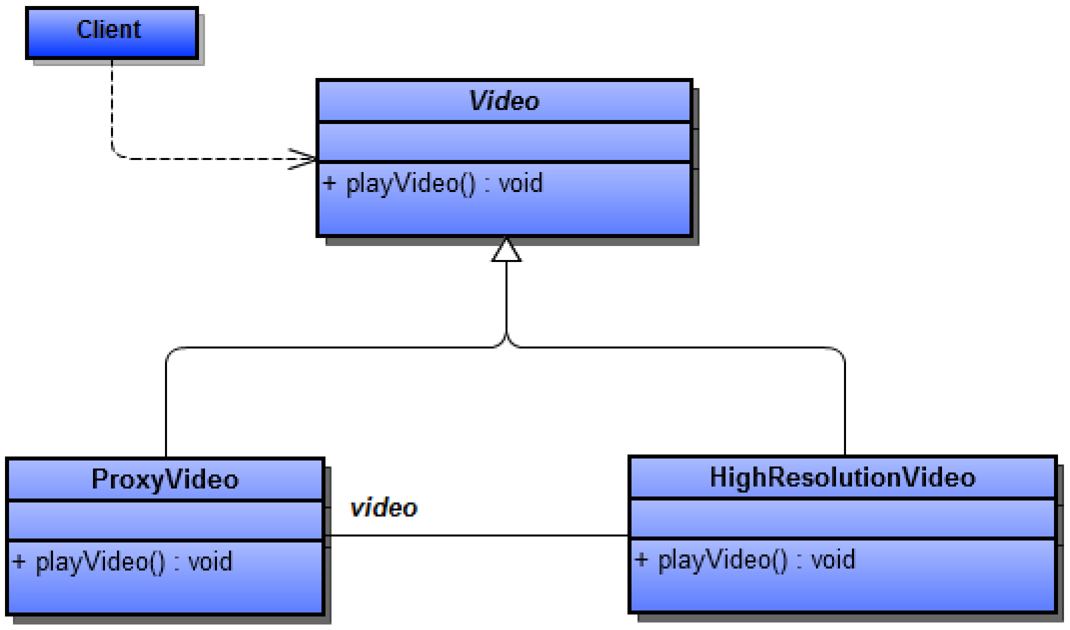


Figure 12: Proxy Pattern.

Consider an example, where client requests a video, without knowing of its content. At this point, it is unclear whether client likes it and wants to watch in higher quality or dislike it and simply close the video stream. In the second case it would be foolish to create an expensive object just to destroy it couple of seconds later. But if he likes it, Proxy provides a control to improve the quality, while ProxyVideo class will contain low quality (typical for YouTube).

Client:

```
public class Client {
        public static void main(String[] args) {
                Video lowQualityVideo = new ProxyVideo();
                Video highQualityVideo = new HighResolutionVideo();

                lowQualityVideo.playVideo();
                highQualityVideo.playVideo();
        }
}
```

Video:

```
interface Video {
        void playVideo();
}
```

ProxyVideo:

```
public class VideoProxy implements Video {
        @Override
        public void playVideo() {
                video = new HighResolutionVideo();
                video.playVideo();
        }
}
```

HighResolutionVideo:

```
public class HighResolutionVideo implements Video {
        @Override
        public void playVideo() {
                // Rendering the video
        }
}
```

3.2.4 Singleton

Singleton is a creational patterns, unlike those, which were discussed previously (they were structural). [6] It is created in a way that ensures the existence of only one instance at a time across the application. [6] For such purpose, constructor defines as a private function, so that it cannot be called from the outside of the class. Instead, common suggestion name for the function is getInstance() which checks whether objects has been instantiated, and if not it creates the object and returns it. If the object has been created previously, function just returns it.

Singleton pattern can be modified depending on the case, to store an array of singletons or gaining an access for the specific group of clients. General structure is the object, which has a reference to itself. Implementation can be lazy, when object is created on-demand inside of the getInstance() function, or early, when object exists as soon as application starts. In case of multithreading application, getInstance() function must be supplied with “synchronized” clause, because of the if statements inside. [6] Usually, singleton is used as a part of Flyweight Pattern, but may exist on its own.

Main purpose of Singleton is to represent authentication instance of user, or share common objects among all the clients. [6] Also, it may be used as real world modelling, for example in one country only one president could exist at a time. Consider the following lazy instantiation example for multithreading system (Figure 13).

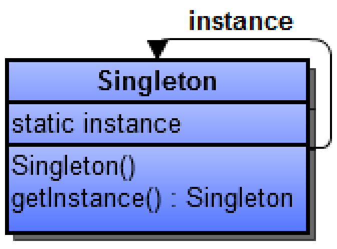


Figure 13: Singleton Pattern.

Singleton:

```
public class Singleton {
        private static Singleton instance;

        private Singleton() {}

        public static synchronized Singleton getInstance() {
                if (instance)
                        return instance;
                else
                        instance = new Singleton();
        }
}
```

3.2.5 Observer

Observer is a behavioural pattern, responsible for handling the evens at run time. One of the biggest challenges in GUI development is to maintain the consistence between the components, but retaining the loose coupling between them at the same time. [6] The model has one-to-many relations to the diagrams, histograms, tables and lists. Such GUI components are called the observers of the model, which can be attached or detached at the run time. Even more, model may have no observers at all, remaining silence until the correct time. When model changes its state (updates inner attributes), observers get notification and changes the corresponding representation as well. [6] All attached observers become synchronized without tight binding to the model.

Observer pattern is used in MVC architectural style, but it is not the same due to the lack of Controller presence.

Consider the example (Figure 14), where the model is a number, and its observers are binary, octal and hexadecimal representations of that number (observers does not necessarily have to deal only with GUI's).

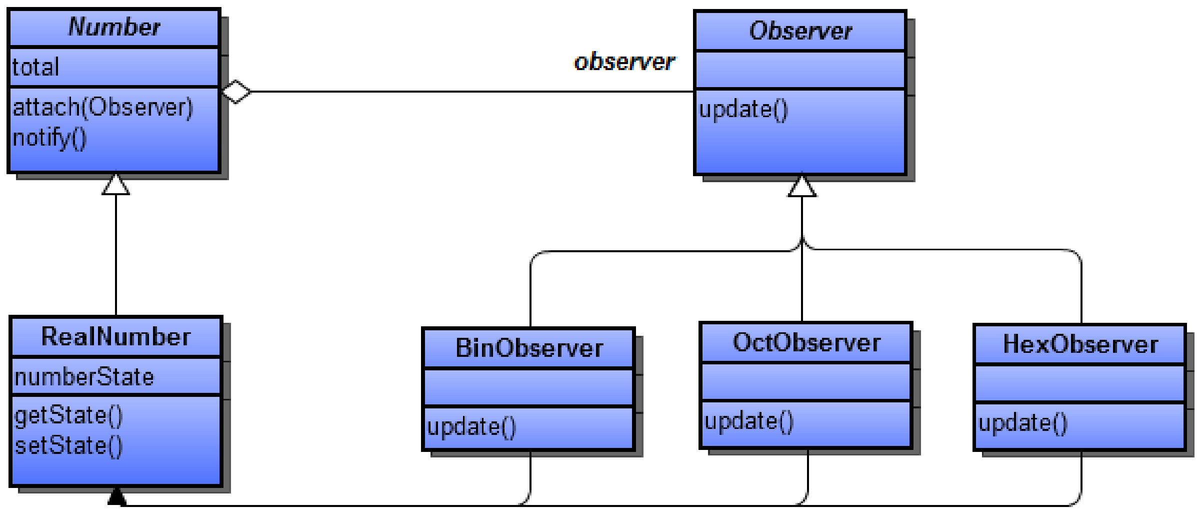


Figure 14: Observer Pattern.

Client:

```
public class Client {
        public static void main(String[] args) {
                Number num = new RealNumber();

                new BinObserver(num); // 1110111100001011001111001111
                new OctObserver(num); // 1674131717
                new HexObserver(num); // EF0B3CF

                num.setState(250655695); // Decimal
        }
}
```

Number:

```
public abstract class Number {
        private int total = 3;
        private Observer[] observers = new Observer[total];

        public void attach(Observer observer) {
                observers[total++] = observer;
        }

        public void dettach(Observer observer) {
                for (int i = 0; i < total; i++) {
                        if (observers[i] == observer) {
                                observers[i] = null;
                                total--;
                        }
                }
        }

        public void Notify() {
                for (int i = 0; i < total; i++) {
                        observers[i].update();
                }
        }

        public int getState() {return 0;}
        public void setState(int in) {}
}
```

RealNumber:

```
public class RealNumber extends Number {
        private int numberState;

        public int getState() {
                return numberState;
        }

        public void setState(int numberState) {
                this.numberState = numberState;
                notify();
        }
}
```

Observer:

```
public abstract class Observer {
        protected Number number;
        public abstract void update();
}
```

BinObserver / OctObserver / HexObserver:

```
public class BinObserver extends Observer {
        public BinObserver(Number number) {
                this.number = number;
                this.number.attach(this);
        }

        public void update() {
                System.out.print(Integer.toBinaryString(number.getState()));
```

```
            }
}
```

4 SOFTWARE DEVELOPMENT PROCESS

After gathering enough theoretical knowledge I am ready to turn them into practical implementation, finally helping the business to make some money. The SaaS system requires the usage of third-party products, coming from 52°North company, implying the knowledge of geospatial data, SensorML xml file description, and architectural styles, software patterns, which are mostly concentrating on service-oriented and multi-tier architectures, and working with spatial database management system.

The goal of the prototype is to develop a system, which includes the data integration component, fetching the data from real measurement device, and web-site, which will allow management and monitoring features to the clients. Such system will prove the ability to transfer data from the device, catch it on the server side, convert the data into meaningful information which will be stored in the spatial database, waiting to be fetched by client and represented on the web-site in different formats, including map view with markers, list view and graphics with exporting features.

Software development process is a software life cycle, which has the following steps [4]:

- Requirement Analysis
- Requirement Specification
- Software Architecture
- Software Design
- Software Implementation
- Software Testing
- Software Deployment
- Software Maintenance

Due to the use of throw-away prototype methodology, all the steps will be done in cycle [4]:

- Requirement Elicitation

- Design Prototype
- Build Prototype
- Test Prototype

Throw-away prototype gathers the requirements, increases the familiarity with the technology and shows the limitations and functionality of the future system. [6] Once the prototype is done, all the documentation remains on the developers' side as well as the knowledge of specific technology tricks — prototype is not fully taken into final product development, only partially. [4] The design will be done again, from the scratch, once the developers had enough time to explore the system. [6] After the outcome of prototyping cycle has been successfully accepted, next steps are [4]:

- Requirement Documentation
- System/Object Design
- Software Implementation
- Software Testing
- Software Deployment
- Software Maintenance

The project involves the understanding the requirements of the Observis Platform, gathering familiarity with Wicket Framework, discovering its suitability for the system, learning the SaaS and PaaS structures in practical implementation, defining the use for 52°North products inside of Observis Platform, gaining experience with spatial DBMS, essentially, PostGIS.

4.1 Software Development Methodology

Methodology specifies the rules for the development process, describing the activities to be executed from the requirements elicitation up to software deployment and maintenance.

Many companies adopted their own software development methodology, but most of them represent a variation of one existing and well-known concept. All methodologies can be divided into following groups [6]:

- **Structural** — Waterfall, V-Model

- **Rapid Application Development** — Phased Model, System/Throw-Away Prototype, Spiral Model
- **Agile** — Extreme Programming Model

Structural models follow the clear path from the beginning to an end, without a possibility to go back. It is suitable for simple, small-size tasks with clear requirements. However, that does not apply to time-limited schedule or projects with unfamiliar technology.

In order to deal with risk management and complex projects, software development activities should be repeated over and over again until the desired functionality is archived [6]. For that purpose Rapid Application Development (RAD) was created, where all of the instances iterate on some activity, it is emphasized in. For example, Phased Model iterates on the testing activity, meaning that all the systems developed with such methodology will be highly reliable [6]. Spiral model iterates in the Descartes system, providing risk management, because after each quarter developers decide whether to go further or fix the problems. [6] RAD methodology is usually seen in systems with unclear requirements, unfamiliar technologies and short time schedule.

Agile methodology focuses on rapid development no matter whether the result archived or not. [6] Functionality must be developed quickly, each task has time-boxes and when the time runs out developer moves to the next task even if the previous was solved only partly. Also, Agile comes handy when developers are dealing with unclear requirements because such quick development allows investigating and discovering certain aspects of the system, which were not seen before at the design activity. [6] However, Agile is not reliable due to the lack of design; therefore complex projects may experience poor quality.

4.1.1 Throw-Away Prototype

Here I will concentrate on the most important methodology related to the thesis. As it was mentioned before, Observis Oy is a start-up company, revealing the fact that it is unclear what the system is supposed to do. Stepping into new technology field is also an issue. Of course, previous knowledge of Java EE platform balances the risks, but there are much more framework to discover. Will the chosen framework fulfil the system needs? Answer to such question can be archived only by trial and error method, which is exactly the purpose of prototyping. Prototyping helps to answer the most frightening question: is the system feasible? Before starting a business and having a real customer, company need to have some kind of presentation. Prove-of-concept requires the usage of prototyping not just for client demonstration purpose, but also for the company itself, helping to understand, whether such thing can even be implemented, and if yes — what are the limitations and possibilities?

Prototype intent is to be built, tested and reengineered until the acceptable requirements are archived, serving as a fundament for the system build. [6] Requirements elicitation is done first, followed by quick design, discovering only the major concepts. After first iteration, prototype is evaluated by the customers or developers to refine the rest of the functionality. Obvious drawback of prototyping is that customer treats the prototype as the final product, complaining on the lack of functionality and possible inconsistency in GUI. Developers have better opportunity of "playing around" with system, trying to explore new edges of the requirements.

Common use of prototyping is not to create the whole system at once, but to create different functionality in several iterations. [6] After that, prototype is considered to be done and may or may not appear as the reference for a real system development. The idea is so, that prototype is never a final product. Increasing the user involvement makes possible to reduce the time and cost of the development. Profit of early prototyping is an ability to test implemented functional, without waiting for the whole system to be done.

Two major streams of prototyping exits in the world of software development. Both of them go through elicitation, design, build and test prototyping cycle; the only one single difference, which clearly distinguishes one from another, is the System/Object Design activity. To begin with, prototyping can be split into two types [4] [6]:

- **System Prototype** — targets the need of product delivery, mainly concentrates on well-understood concepts so that first version will contain the expected functionality, requested by the user. After prototyping is finished, system prototype is retained and used as the reference for developing the final product. The name System clearly defines that the design is done during prototyping. Once the prototype is accepted, go straight to the implementation activity; do not need to redesign the system.
- **Throw-Away Prototype** — in contrast with System Prototype, it targets the requirement elicitation, and discarded (thrown away) once this activity is completed. Because of that, developers might experience attachment to the all the hard work they put into

prototype even if it does not satisfy user. Throw-Away Prototype helps eliminate that problem, since from the very beginning developers understand that their work will be thrown away. Typically the development is concentrating on the least understood concepts, in comparison with system prototype.

Bottom line, throw-away prototyping literally means [4] [6]:

- develop a prototype
- gather requirements, get familiar with technology, understand the complexity
- throw away the prototype
- start again from the requirement documentation followed by System/Object Design

Developing a prototype, especially throw-away prototype, requires significant investments, because during this stage, client does not get any product, therefore company does not receive any money [4]. Nevertheless, company will benefit from the prototyping on the long run.

4.2 Requirement Analysis and Specification

Software Requirement Specification (SRS) defines the system from the customers' point of view, while analysis model defines the system from developers' prospective. [6] Requirement elicitation was done based on the previous developers' group experience with spatial systems and current trends of ecological companies, which were observed via the media and personal contacts.

The current situation of the clients is so, that companies need to host their spatial data into a service, which will provide content management features over it, including map visualization, historical data records, different form of graphics and also the component, which will convert data into information in a meaningful way to the client. The scope statement of SRS defines the system, as platform rather than product, meaning that there will be no delivery to the user, instead it will provide an access to its capabilities. The system must be developed from the scratch with unclear requirements, using unfamiliar technology and having long-term schedule. That is the reason, why prototyping will be used for such system, even further, because company wants to have more control over the system and be flexible to arising changes, throw-away prototype will be used over system prototype.

It was decided to outsource the part of the system, responsible for translating the spatial data from the application layer to database (data access layer). However, some of the operation will be done directly, therefore I will split data access layer into two parts. Everything else will be developed as a part of the future system, where presentation layer will be oriented for browsers only as the first effort.

Deployment environment will not be outsources, and will remain in companies server under Linux operating system, implementing the Platform level in cloud computing. Application server, which is Apache Tomcat, will provide the connection to PostGIS spatial database, which is an extension of PostgreSQL. Java EE technology will be used for Software level, in form of Wicket Framework plus number of other third-party libraries to support the development.

Prototyping will be divided into following components:

- **Yahoo Fetcher** — first of all, weather data must be collected via an open XML API, providing future dummy object for feeding the spatial database
- **SOS integration** — secondly, system need an integration component, which will utilize the Sensor Observation Service (SOS) capabilities from 52°North on data access layer and allow to fire events for it from the application logic layer on the Wicket side
- **Data Browser** — now that system gained the data and can manage them on the database side, system can display them to the end client and finally make something useful. However, the data browser itself holds a number of items:
    - **Map Page** — displays the OpenLayer maps, such as custom made, GMaps and OpenStreetMaps with markers and pop-ups
    - **List Page** — displays the data in list format with exportable features
    - **Graph Page** — displays the data in form of line and pie charts with saveable feature
    - **Administrator Page** — allows to manage the database via SOS integration

Delivery timeline for decomposed system includes following stages:

- Familiarity with Wicket Framework and system structure — 1 week
- Integration of Wicket and SOS — 2 weeks
- Developing dummy data supplier (Yahoo Fetcher) — 1 week

- Developing Data Browser:
  - Map Page — 3 weeks
  - List Page — 3 weeks
  - Graph Page — 3 weeks
  - Administration features — 3 weeks

Meanwhile after each step, dependencies should be modified, for example when creating new features for administration purpose, it may require modifying and re-engineering the integration with SOS. Constant development of every part of the system will be defined in story cards, representing very small, but precise changes, bug fixes or improvements.

Acceptance criteria testing will include following considerations:

- System must benefit from Wicket Framework best practice
- Integration with SOS must be able to manage (read, write, modify, delete) the following entities
- Yahoo Fetcher must be able to take the weather data from yahoo XML service and feed it into the PostGIS via integration component
- Data Browser's users must have the same experience in Safari, Opera, IE, Chrome and Firefox using Mac OS X, Win X, Linux operating systems. Multiple users fetching the data at the same time should be supported as well as reasonable response time. Design and GUI should be nice to look and easy to use:
  - Map Page must display the third-parties maps and be able to put markers all over it with pop-up dialogs
  - List Page must be able to present data in list form with basic management features, such as searching, dividing large amount of data by pages, export to CSV and PDF
  - Graph Page must be able to display the data as pie-chart and line-chart allowing to put markers with pop-up information and filtering options
  - Administrator Page must be able to provide management features for SOS entities for integration and authentication and authorization for Wickets Framework annotations

Observis Platform is a common name for measurement information gathering, storing, analyzing and publishing platform that is operated by Observis Oy. The services are offered from a cloud in a SaaS (Software as a Service) and PaaS (Platform as a Service) manner. Essentially this means that Observis operates and maintains the platform components in hosted servers and allows customers access to the user interfaces and capabilities of the platform following the pay-as-you-go principle.

From abstract point of view, Observis Platform is expected to offer following functionalities:

- Gathering data from any type of remote or local measurement device
- Gathering data from any type of measurement information publishers
- Storage of gathered data
- Analysis of measured data
- Storing analysis data
- Flexible visualisation of stored data
- Customized user interfaces for different clients
- Customized user interfaces for data provider partners
- 3rd party analysis service and software integrations
- In-built GIS features
- Ability to integrate with common map services such as Google Maps
- Ability to use proprietary map services as source of UI GIS information

4.2.1 52°North Sensor Observation Service

Observis Platform is taking advantage out of Germany 52°North products. SOS (Service Observation Service) demands to read live, in-situ and remote sensors. The service allows the data to be passed and retrieved to and from the spatial database for the benefit of other third-party services.

Because this database was built in PostGIS, it follows the spatial database convention, where geometry types could be a polygon, a line or a point, making possible to execute the operations, such as polygon overlapping and distance between two points. However, to store the geometry data it is essential to provide an appropriate SensorXML for it. For example to store the textType “**<swe:Text>**” section must be used, for numericType — “**<swe:Quantity>**”, for spatialType — “**<swe:Position>**”.

Consider the SOS database schema on Figure 15 (notice, that there is an error, in table "phenomena", attribute "value_type" does not exist, and instead it is just "valuetype"):

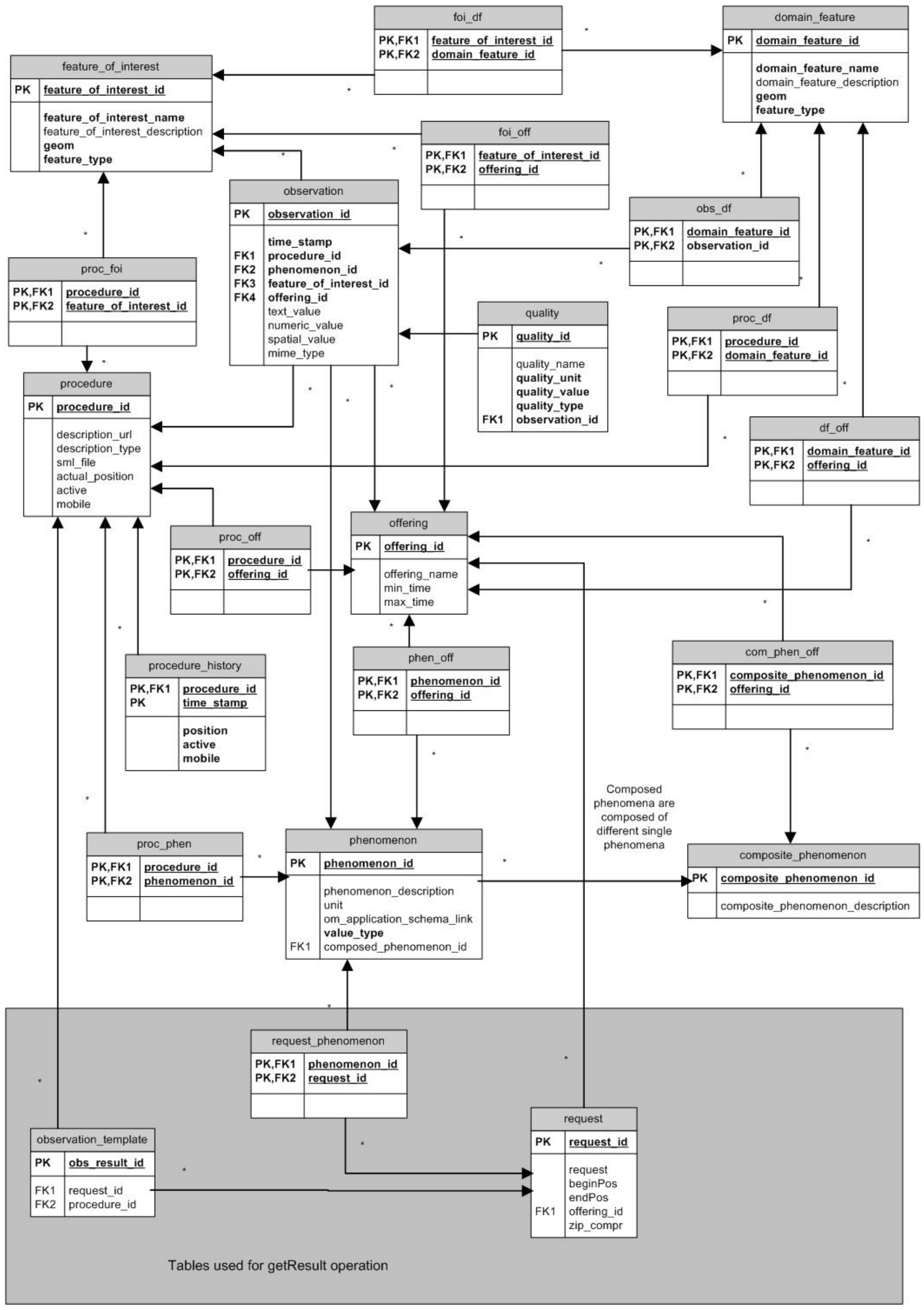
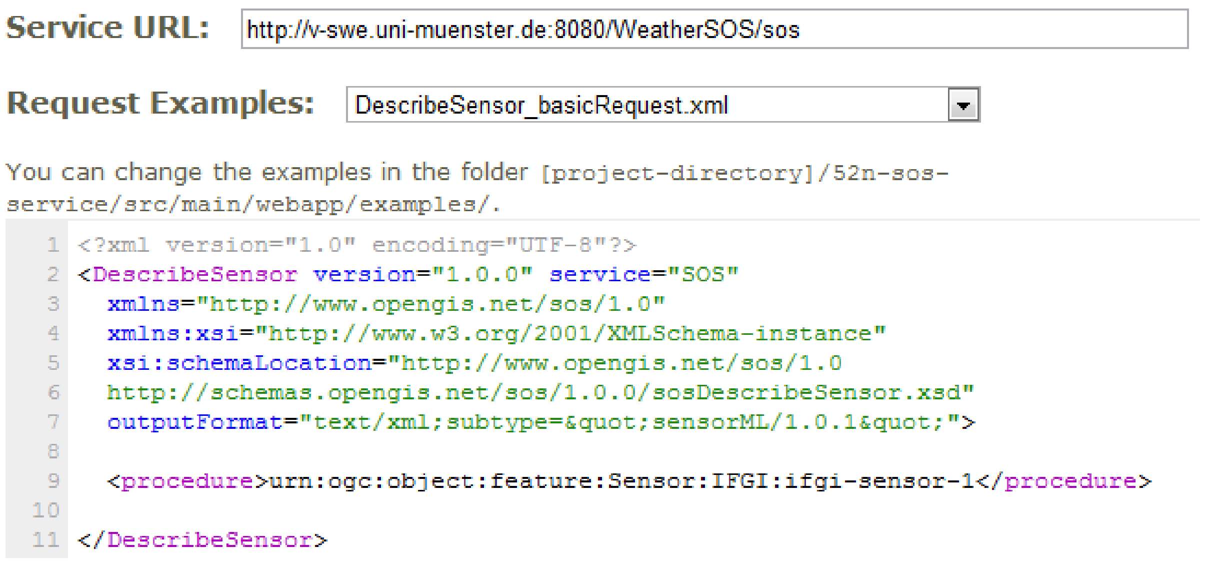


Figure 15: 52°North SOS Database Structure. (52°North Documentation)

SOS provides an interface in XML format for data manipulation on the high level of abstraction. Also, it provides testing interface out of the box on your downloaded version or for the public audience from the net: http://v-swe.uni-muenster.de:8080/WeatherSOS/. On Figure 16, client wants to see the details of the "ifgi-sensor-1.



Service URL: http://v-swe.uni-muenster.de:8080/WeatherSOS/sos

Request Examples: DescribeSensor_basicRequest.xml

You can change the examples in the folder [project-directory]/52n-sos-service/src/main/webapp/examples/.

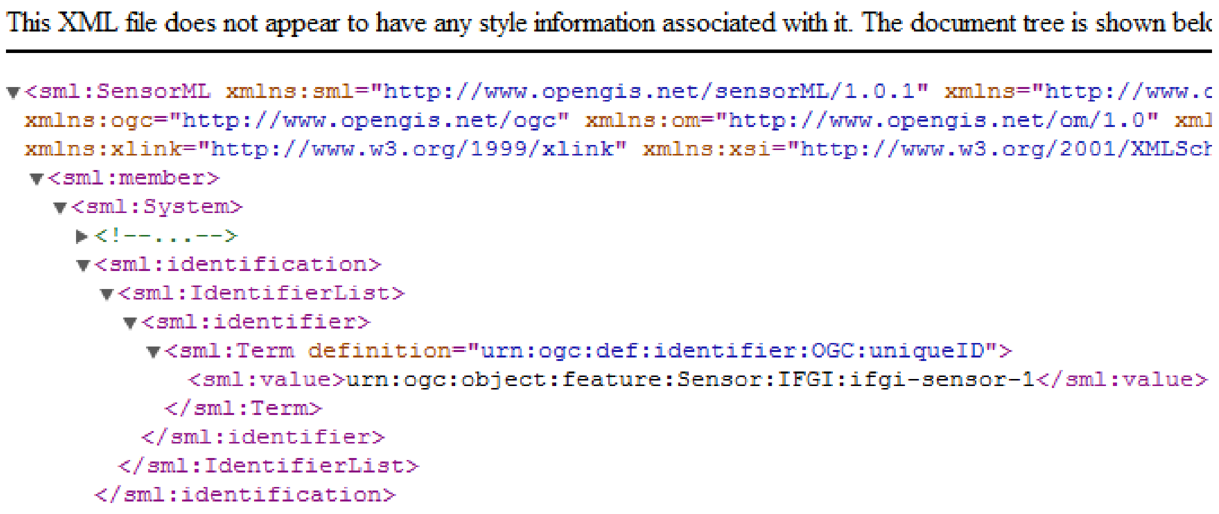
```
<?xml version="1.0" encoding="UTF-8"?>
<DescribeSensor version="1.0.0" service="SOS"
  xmlns="http://www.opengis.net/sos/1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.opengis.net/sos/1.0
  http://schemas.opengis.net/sos/1.0.0/sosDescribeSensor.xsd"
  outputFormat="text/xml;subtype=&quot;sensorML/1.0.1&quot;">

  <procedure>urn:ogc:object:feature:Sensor:IFGI:ifgi-sensor-1</procedure>

</DescribeSensor>
```

Figure 16: 52°North SOS Describe Sensor Request.

If I feed that XML into SOS, the response will be a SensorML file (in case if the sensor was previously registered). Figure 17 shows the response from SOS.



This XML file does not appear to have any style information associated with it. The document tree is shown bel

```
▼<sml:SensorML xmlns:sml="http://www.opengis.net/sensorML/1.0.1" xmlns="http://www.c
 xmlns:ogc="http://www.opengis.net/ogc" xmlns:om="http://www.opengis.net/om/1.0" xml
 xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSch
  ▼<sml:member>
    ▼<sml:System>
      ▶<!--...-->
      ▼<sml:identification>
        ▼<sml:IdentifierList>
          ▼<sml:identifier>
            ▼<sml:Term definition="urn:ogc:def:identifier:OGC:uniqueID">
                <sml:value>urn:ogc:object:feature:Sensor:IFGI:ifgi-sensor-1</sml:value>
              </sml:Term>
            </sml:identifier>
          </sml:IdentifierList>
        </sml:identification>
```

Figure 17: 52°North SOS Describe Sensor Response.

Besides that, SOS has a wide range of other useful operations from common xml format to SOAP and mobile sensor. However, there are limitations, which can be avoided only in case of direct JDBC (Java Database Connector) usage.

52°North SOS is based on 4-tier architecture and represents a separate service hosted on the application server. The entire service will be treated as single layer, but inside as a standalone service, it has 4 tiers, as shown on Figure 18.

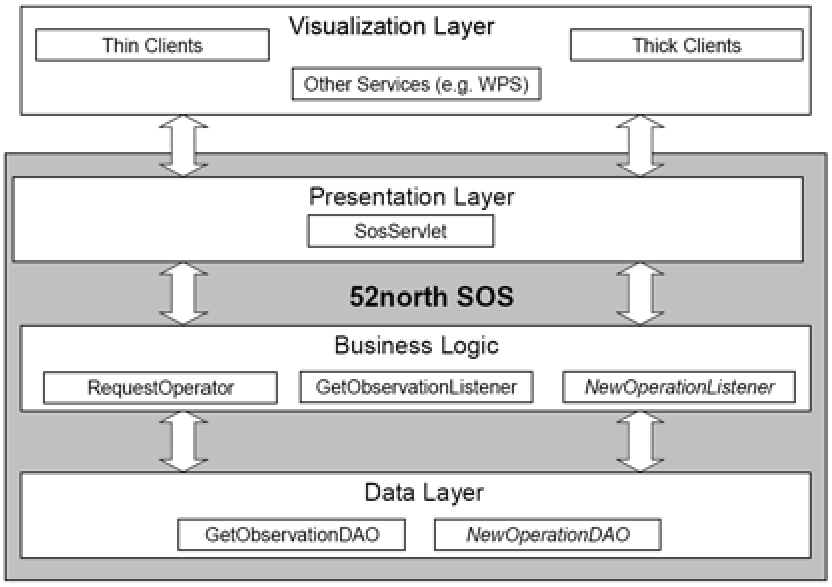


Figure 18: 52°North SOS 4-tier architecture. (52°North Documentation)

4.2.2 Functional Requirements

Functional requirements describe the interaction between the system and its environment independently of implementation. [6] The environment includes the user and any other external system, with which the system interacts. Functional requirements will be also divided by the components of the prototyping development along with the general system outline.

Because of business idea's sensitivity, I will not reveal critical information unless it is already available in public, such as Wicket examples, Yahoo Weather API and 52°North's SOS.

Yahoo Fetcher functional requirements are:

- Component must fetch the data via Yahoo Weather XML API
- Component must form the XML input file based on the fetched data merging the resulting XML from Yahoo Weather and XSLT template file
- Component must check whether the yahoo sensor information exists in the database, if not — add the sensor first, if yes — and the formed XML file

- Component must be loosely coupled for configuration with different SOS services and different parameters
- Component must supply the database with any 10 towns in North America and Europe, where the information will be fetched every hour and saved in the database based on the timestamp of the Yahoo Weather XML (if the timestamp is the same as previous — do not insert new record)

SOS Integration functional requirements are:

- Component must be loosely coupled for configuration with different SOS services and different parameters
- SOS must retrieve the model of the system at the start-up
- SOS must be stored in the Wicket session across the pages
- SOS handles the model manipulation for administrator page functionality as well as supplied functions

Data Browser functional requirements are:

- Data Browser has 4 pages for user purpose: Map Page, List Page, Graph Page, 360 Page (this one is omitted due to its simplicity); and 1 page for administration of the database — Administration Page
- Data Browser has 3 scrollable panels with items. Each panel's behaviour must depend on the selected page.

Map Page functional requirements are:

- Map Page must be display the multiple maps and allow to switch from one to another
- Map Page must represent the information in form of the markers and pop-ups
- Map Page must be able to zoom and move view
- Map Page should allow the marker filtering via mouse operations
- Map Page must display markers in circle when multiple markers has the same lat/lon
- Map Page pop-up details must be redirected to List and Graph Page is desired
- Data Browser panels must filter the markers based on its selection

List Page functional requirements are:

- List Page must display the data in table format by timestamp and value
- List Page allows to filter the rows by timestamp or value
- List Page allows to export the filtered/non-filtered data into different formats
- List Page displays the entire data array by portions in form of pages
- List Page allows sorting feature based on value or timestamps
- Data Browser panels must select the viewed items based on its selection

Graph Page functional requirements are:

- Graph Page display the graph in two formats: pie chart and line chart
- Graph Page allow to save the current image of the graph
- Graph Page allow to expand itself to a bigger window
- All the lines of the items must have distinguished colour
- Graph Page shows relations between timestamps and selected items
- Line Chart allow to filer the items inside of the graph
- Each edge point must be supplied with pop-up, in case of having more than one points on the same position — pop-up must show all of them
- Data Browser panels must select the viewed items based on its selection

4.2.3 Non-Functional Requirements

Non-functional requirement describe non-direct actions, related to the functional behaviour of the system. [6] For example, is could be quality requirement, such as usability, reliability, supportability or performance desires. Other example is the constraints: legal, interface or operational requirements. Best practice is to eliminate any constraints from the requirement, defining the methodology, programming language or use of specific IDE (Integrated Development Environment) because it may slow the project or even make is ambitious. [6]

Observis Platform SRS does not specify any implementation or legal constraints, even further it is open for usage of new technologies, rather than staying in the one field with one prospective.

Quality non-functional requirements are:

- Data Browser must be accessible via following browsers: Safari, Opera, Chrome, Firefox, Internet Explorer; running under one of the following operating systems: Linux, Win X and Mac OS X. In any case, the user experience must remain the same
- Development of prototype up to acceptance criteria must take no longer than 4 month

Performance non-functional requirements are:

- System must allow access for the multiple users at the same time
- Integration component for gathering the model of spatial database must take no longer than 30 seconds to retrieve the data

Reliability non-functional requirements are:

- Administrator Page should be secured with authentication and authorization
- Non- authenticated user must not have the ability to create, update or delete information from the database
- Authenticated user must perform all changes in atomic way to ensure consistency of the database
- Errors on the Administration Page should be displayed in user-friendly format, in case of faults, all operations must be rolled back
- System should be available 24/7/365 under normal circumstances

Supportability non-functional requirements are:

- System shutdown must not take longer than 4 hours to upgrade the service
- System must be able retain portability across multiple application servers
- System should follow component-based style to wrap and reuse the components

Usability non-functional requirements are:

- GUI must be user friendly and does not require study any manuals before the usage
- Use of GUI must look aesthetically correct and be fluent in interaction, eliminating the unnecessary usage of keyboard, utilizing mouse scroll wheel for listing the data

Interface non-functional constraints:

- System has to utilize the 52°North SOS as data access layer
- Yahoo Fetcher must use XML and XSLT merging

The system also has a number of dependencies, excluding every-time required:

- Wickets Framework libraries: wicket-extensions, wicket-auth-roles, wicket-datetime
- JSON Simple for JSON string creation on Graph Page
- OpenLayers integration for Map Page
- jQuery for GUI interaction and data manipulation on List Page
- XStream for loosely coupled configuration
- DOM4J libraries to support XML-file operations
- JAXEN for XPath for XML-file operations
- OpenFlashChart 2 libraries for data visualization

4.2.4 Scenarios and Use Cases

Use cases helps to define the user functionality in graphical form. Being supplied with actors and use case scenarios, they explain the particular situation, which may happen at the running time. [6] I will provide only one example of the scenario, followed by the first effort use case description and refined use case description, otherwise the amount of work for each single use case will exceed any feasible boundaries. Also, I will draw a simplified use case diagram of the system.

Use case has actors, which represent roles of the users, which interact directly to the system. System actors (external entities that interact with the system) are:

- **Client** — end-user who wish to view the information
- **Administrator** — customer who wish to manage the information

Scenario is "a narrative description of what people do and experience as they try to make use of computer systems and applications". [4] In other words, scenario is an instance of the use case, describing the concrete situation, without any paths or decisions. [4] [6] For example, consider company wants to investigate what is happening when user wants to see and export the details of the temperature from the system:

Scenario name	**viewTemperatureDetails**
Participating actor	Homer:Client
Flow of events	1. Homer opens the browser, types the address of the system web site and hits Enter. New session is started by fetching the model from the database. The home page redirects him to the Map Page of the system. 2. Homer scrolls through the items in the panels using the mouse wheel and selects his home town and temperature items. By default all items were selected. 3. Homer sees the marker on the map over his town, zooms in using the map controls. 4. It turns out that only one marker exists on the desired place, therefore Homer simply clicks the temperature icon using left mouse button and the pop-up appears on the left-bottom side from the icon with the detains of the place, position and current temperature 5. Homer wants more, and he presses the "View in List for-mat" icon, which redirects him to the List Page with pre-served selections 6. Being interested in the days, where temperature was exactly 15 degree, Homer type number 15 into search form and the list automatically filters the rows, where value is equal to the requested. 7. Homer is exited with the results and wants to share it with his friends, in order to do so; he clicks the button, saying "PDF" and chooses the location to save the table in PDF format. 8. Once the document has been saved, Homer closes the browser, terminating the session.

It may seem that scenario is the same as use case, but it’s not due to the decisions and abstract nature of the use case. Now that I identified the flow of events for the particular Homer actor, let’s move further and create an abstract of that scenario defining the use case description:

Use case name	**viewMapPageAndListPage**
Participating actor	Initiated by Client
Entry condition	• Client opens the browser, types the address of the system web site and hits Enter. • New session is started by fetching the model from the data-base. • The home page redirects him to the Map Page of the system.
Flow of events	1. Client selects the desired combination of place and item to view. a. System filters the markers on the map. 2. Client navigates to the place of his interest using map con-trols. a. Single marker is located in the position, OR b. Multiple markers are located around the position in circle form; the position itself has unclickable de-fault marker. 3. Client clicks the marker. a. System displays the information about place, posi-tion and current item value in pop-up. 4. Client clicks the icon, leading to the ListPage. a. System loads the ListPage with preserved selections. 5. Client enters the desired value into search field. a. System filters the rows by the desired value. 6. Client hits the format button. a. System opens the save dialog to chose the location for saving the filtered results in chosen format.
Exit condition	• Client closes the browser, terminating the session, OR • Wait time exceed the 30 minutes limit.
Quality requirements	• Data Browser must be accessible via following browsers: Safari, Opera, Chrome, Firefox, Internet Explorer; running

	under one of the following operating systems: Linux, Win X and Mac OS X. In any case, the user experience must remain the same • System must allow access for the multiple users at the same time • Integration component for gathering the model of spatial database must take no longer than 30 seconds to retrieve the data

Refining the use cases description is important part of the software elicitation. As you can see from the scenario, Homer actually performed two actions during the same session: view the details of the temperature on the Map Page and export the filtered data on the List Page. The first attempt of our use case just represented an abstract of such scenario. But now that I examined those two different actions, I can move further and split the List Page part into viewing data in table format from filtering and exporting them. It is perfectly fine to copy paste the use case descriptions, split them into parts and redo the same part all over again, because the system design will benefit from clear requirements on the long run.

After the refining process, instead of having viewMapPageAndListPage use case I will archive the distribution of responsibilities, resulting into use cases:

- applicationSession
- viewMapPage
- viewMapPageMarker
- viewListPage
- viewListPageFilter
- viewListPageFormat
- connectionDown

Application Session will be a major use case, handling all quality requirements and includes the Map and List Pages use cases. Purpose of it is to fetch the model and remain calm until the user actions or termination conditions:

Use case name	**applicationSession**

Participating actor	Initiated by Client
Entry condition	• Client opens the browser, types the address of the system web site and hits Enter.
Flow of events	1. System fetches the model from the database. 2. System remains in idle state, waiting for user actions. a. Client may fire the MapPage or ListPage.
Exit condition	• Client closes the browser, terminating the session, OR • Wait time exceed the 30 minutes limit.
Quality requirements	• At any point during the flow of events, this use case can include the viewMapPage and viewListPage use cases. • Data Browser must be accessible via following browsers: Safari, Opera, Chrome, Firefox, Internet Explorer; running under one of the following operating systems: Linux, Win X and Mac OS X. In any case, the user experience must remain the same • System must allow access for the multiple users at the same time • Integration component for gathering the model of spatial database must take no longer than 30 seconds to retrieve the data

viewMapPage occurs after session initialization and may include the viewMapPageMarker:

Use case name	**viewMapPage**
Participating actor	Initiated by Client
Entry condition	• Application session has been started • Map Page has been opened.
Flow of events	1. System displays the map with all items selected by default and presented in form of the markers. 2. Client selects the desired combination of place and item to view. a. System filters the markers on the map.
Exit condition	• Client leaves the MapPage.
Quality requirements	• At any point during the flow of events, this use case can in-

	clude the viewMapPageMarker use case. • GUI must be user friendly and does not require study any manuals before the usage. • Use of GUI must look aesthetically correct and be fluent in interaction, eliminating the unnecessary usage of keyboard, utilizing mouse scroll wheel for listing the data.

Client can execute the viewMapPageMarker use case, which may include the viewListPage:

Use case name	**viewMapPageMarker**
Participating actor	Initiated by Client
Entry condition	• Map Page has been viewed
Flow of events	1. Client navigates to the place of his interest using map controls. a. Single marker is located in the position, OR b. Multiple markers are located around the position in circle form; the position itself has unclickable default marker. 2. Client clicks the marker. a. System displays the information about place, position and current item value in pop-up. 3. Client may click the icon, leading to the ListPage. a. The viewListPage use case is included here.
Exit condition	• Client leaves the MapPage.
Quality requirements	• none

Following use case may appear either after the application start or from viewMapPageMarker:

Use case name	**viewListPage**
Participating actor	Initiated by Client
Entry condition	• Application session has been started • List Page has been opened.
Flow of events	1. System displays the ListPage with a. All items selected by default and empty table, OR

	b. Selection was passed as a parameters and table contains the pair of location and item value without filtering
Exit condition	• Client leaves the ListPage.
Quality requirements	• At any point during the flow of events, this use case can include the viewListPageFilter and viewListPageExport use cases. • GUI must be user friendly and does not require study any manuals before the usage. • Use of GUI must look aesthetically correct and be fluent in interaction, eliminating the unnecessary usage of keyboard, utilizing mouse scroll wheel for listing the data.

ListPage use case enhanced by the filter and export options:

Use case name	**viewListPageFilter**
Participating actor	Initiated by Client
Entry condition	• Application session has been started • List Page has been viewed.
Flow of events	1. Client enters the desired value into search field. a. System filters the rows by the desired value.
Exit condition	• Client leaves the ListPage.
Quality requirements	• none

Use case name	**viewListPageFormat**
Participating actor	Initiated by Client
Entry condition	• Application session has been started • List Page has been viewed.
Flow of events	1. Client hits the format button. a. System opens the save dialog to chose the location for saving the filtered results in chosen format.
Exit condition	• Client leaves the ListPage.
Quality requirements	• none

One more important use case has the exceptional behaviour, which is unlikely to happen:

Use case name	**connectionDown**
Participating actor	Client communicates with the system
Entry condition	• This use case extends the applicationSession use case. It is initiated by the system whenever the network connection between the database and presentation layer is lost.
Flow of events	1. System displays the error message. 2. System rolls back the model to preserve the atomic state.
Exit condition	• Client closes the browser, OR • Connection is successfully re-established.
Quality requirements	• none

Use case diagram (Figure 19) combines the actor and all use cases with their relationships:

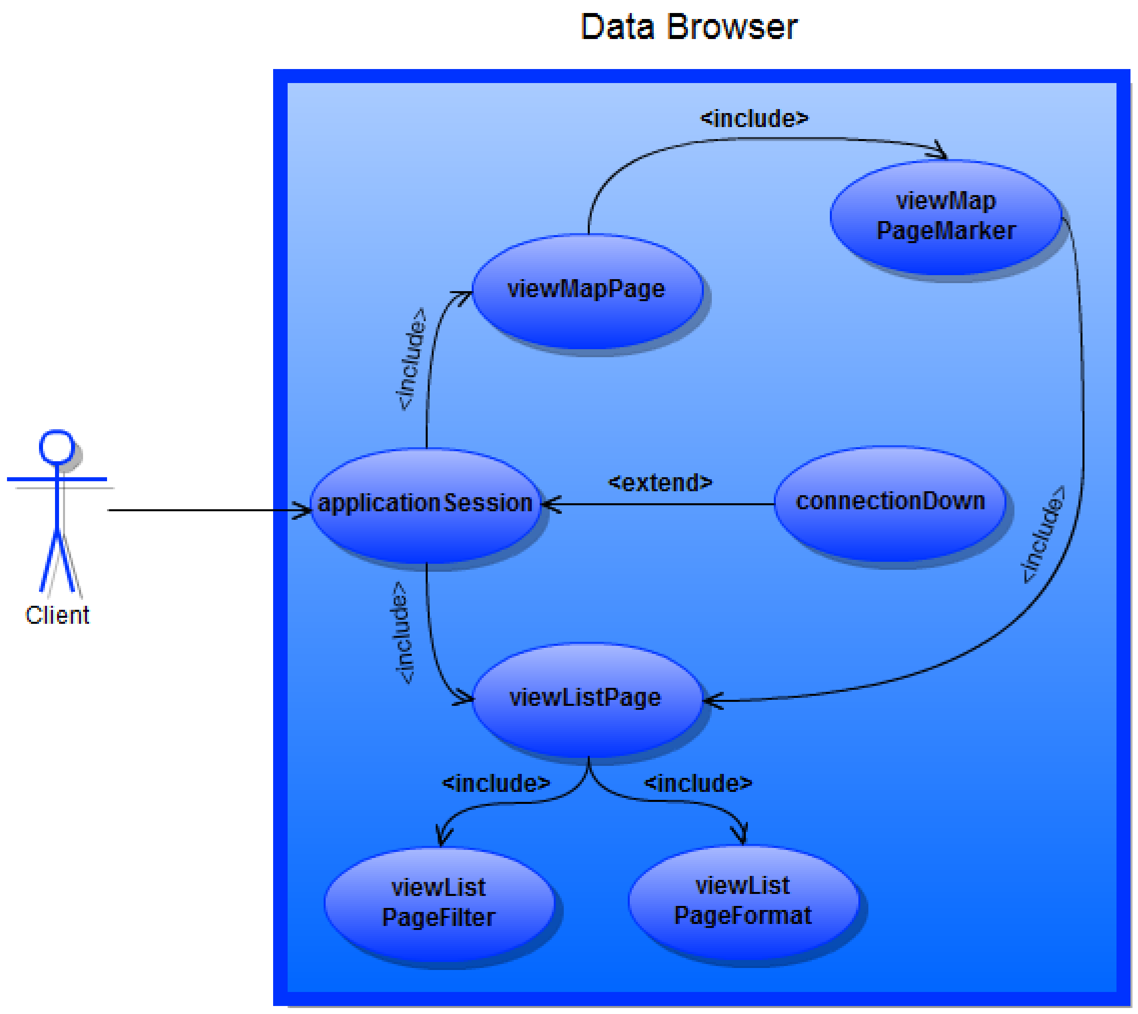


Figure 19: Use Case Diagram for MapPage and ListPage.

This way the system functionality is described. Each use case on the use case diagram must be accompanied with a use case description.

4.3 Software Architecture and Design

Software architecture and design finds its appearance in UML (Unified Modelling Language) format, including class, component, sequence and state diagrams. Our prototype will follow the service-oriented architecture, while Wicket Framework will preserve the MVC style for presentation layer. System will consist of following layers (Figure 20):

- **Presentation layer** — Wicket components, jQuery, html, css, OpenFlashChart for GraphPage and OpenLayers integration for MapPage
- **Application Logic layer** — Wicket pages will hold the controller responsibilities as well, but main logic will stay in form of POJOs of SOS integration component
- **Data Access Layer** — 52°North SOS will handle communication with spatial data-base, however some operations will be done via JDBC
- **Spatial DBMS** — PostGIS with 52°North SOS database schema

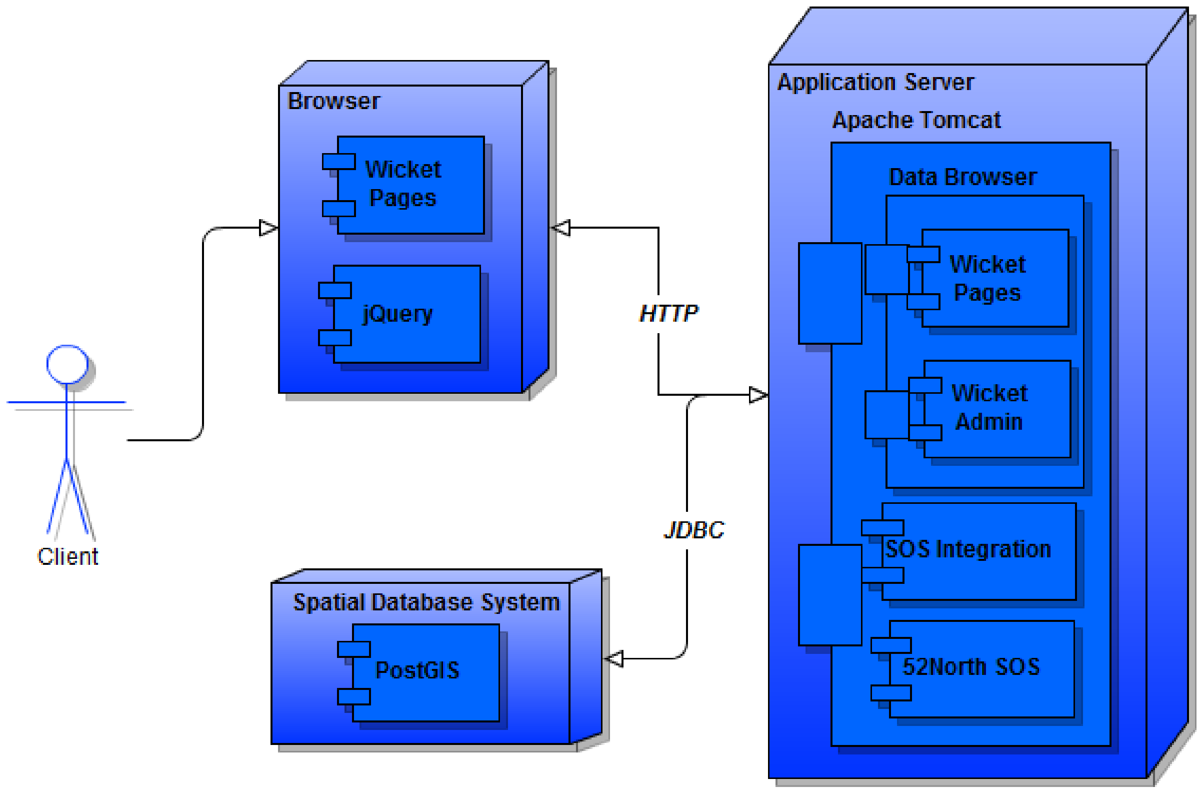


Figure 20: Prototype Deployment Diagram.

Presentation layer content will always be in HTML/CSS format with OpenLayer extension for js, jQuery for ListPage and panels plus OpenFreeChart for GraphPage. Commmunication in between the client and application server will remain in simple HTTP (Hyper Transfer Protocol) format. Inside of the application logic, SOS integration will process the queries to the database from wicket pages (DataBrowser) to the 52°North SOS. Wicket operates on both presentation and application logic levels, tiding together the view and controller. Figure 21 shows the layered outline of the system.

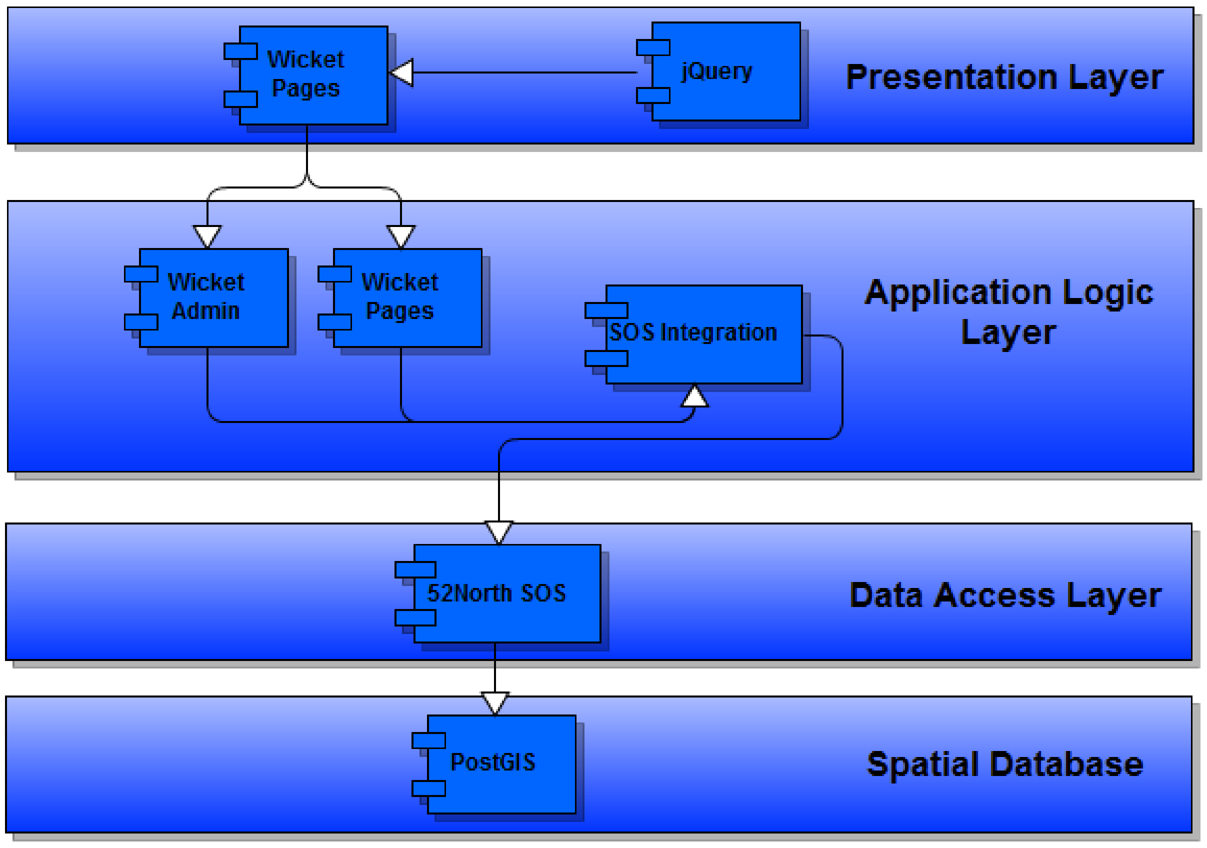


Figure 21: Multi-tier Prototype Architecture.

4.3.1 Yahoo Fetcher

Yahoo Fetcher's only purpose is to feed the database with dummy data. It connects to the YahooWeather XML API with URL request and receives an XML file as a response. Because of XML nature of such component, I will use XSLT for merging files based on rules to match the syntax of SOS xml query request. Source XML will be fetched from the Yahoo server; therefore two XSL files should be presented to transform it into appropriate format and one

XML for checking the presence of the sensor. Figure 22 shows the data flow diagram of the component.

The intent is as following:

- Fetch the XML based on the city zip ID
- Save results as XML file
- Check whether the sensor exists in the SOS database
    - If Yes — feed the data
    - If No — register the sensor and then feed the data

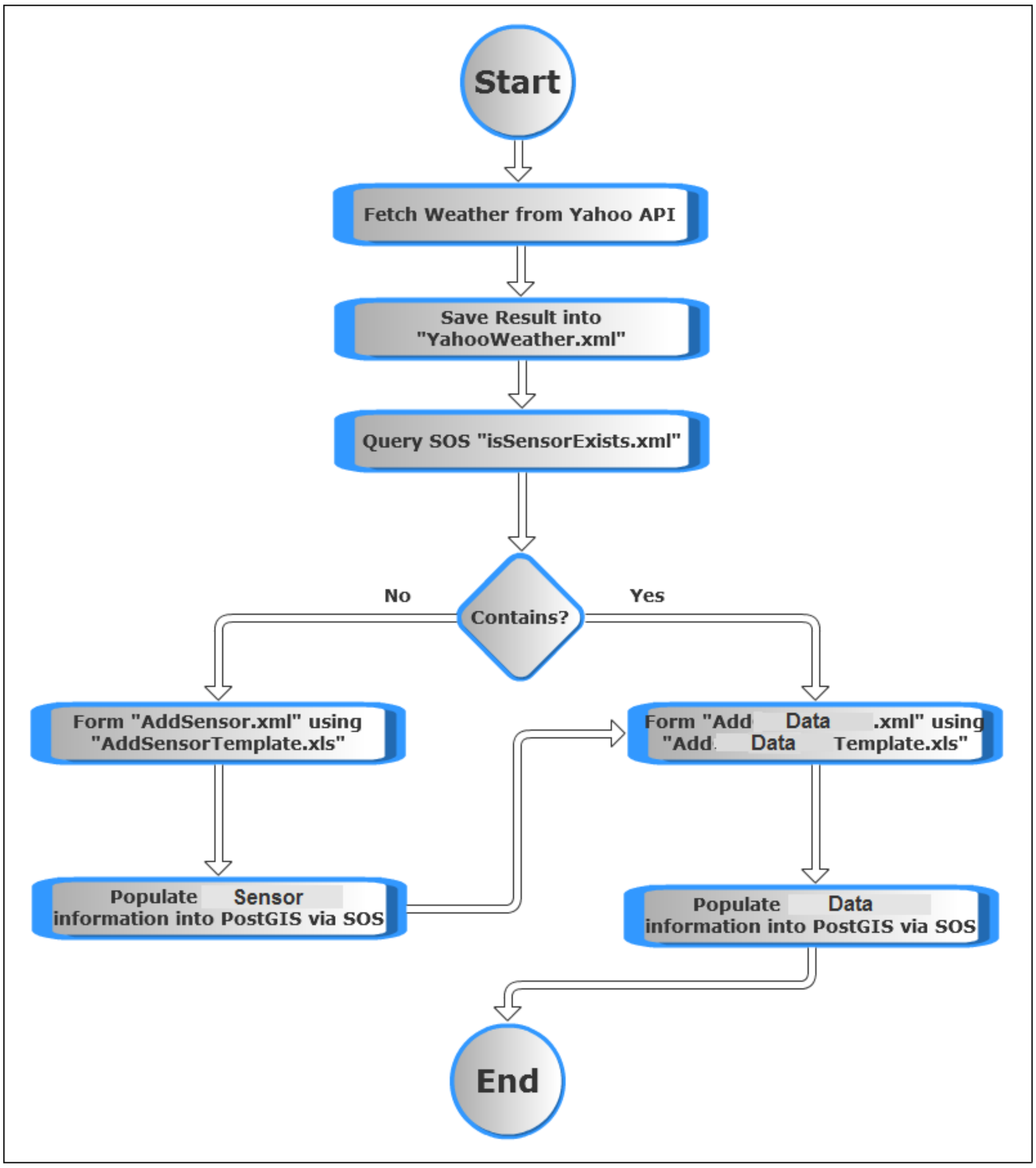

Start
Fetch Weather from Yahoo API
Save Result into "YahooWeather.xml"
Query SOS "isSensorExists.xml"
No
Contains?
Yes
Form "AddSensor.xml" using "AddSensorTemplate.xls"
Form "Add Data .xml" using "Add Data Template.xls"
Populate Sensor information into PostGIS via SOS
Populate Data information into PostGIS via SOS
End

Figure 22: Yahoo Fetcher Control Flow.

The component is fairly simple one and consists of only one class (Figure 23).

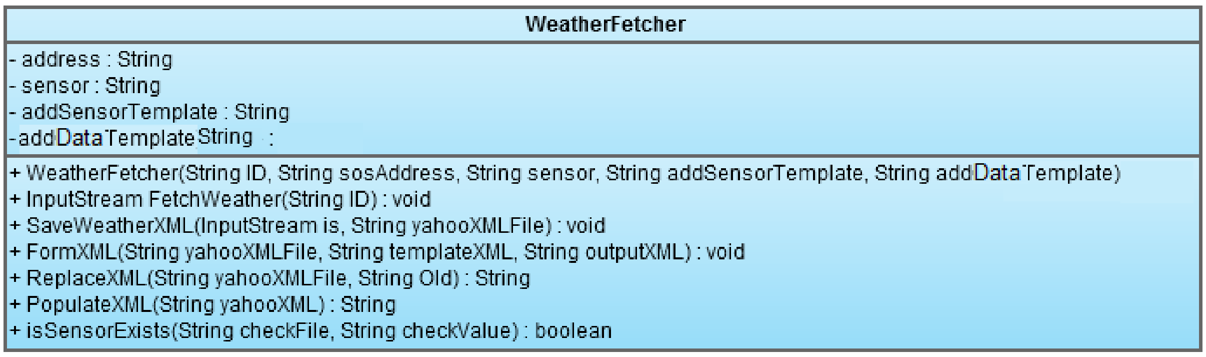

WeatherFetcher
- address : String
- sensor : String
- addSensorTemplate : String
- addDataTemplate String :
+ WeatherFetcher(String ID, String sosAddress, String sensor, String addSensorTemplate, String addDataTemplate)
+ InputStream FetchWeather(String ID) : void
+ SaveWeatherXML(InputStream is, String yahooXMLFile) : void
+ FormXML(String yahooXMLFile, String templateXML, String outputXML) : void
+ ReplaceXML(String yahooXMLFile, String Old) : String
+ PopulateXML(String yahooXML) : String
+ isSensorExists(String checkFile, String checkValue) : boolean

Figure 23: Yahoo Fetcher Class Diagram.

Sequence diagram will explain the communication flow in between the components (Figure 24).

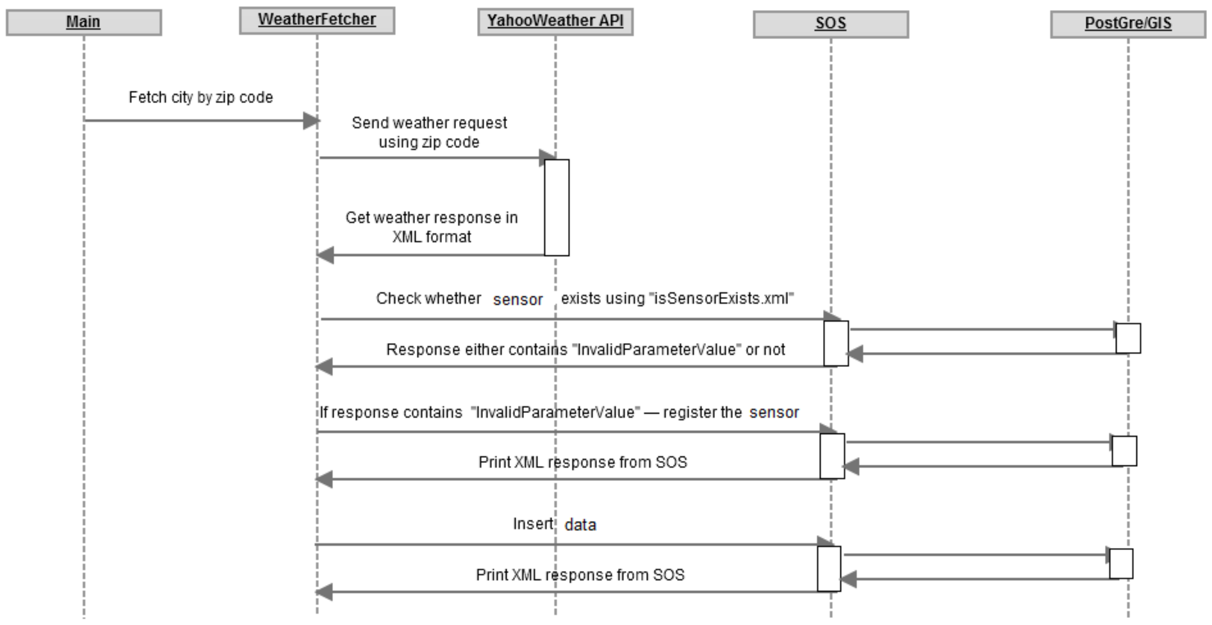

Main
WeatherFetcher
YahooWeather API
SOS
PostGre/GIS
Fetch city by zip code
Send weather request using zip code
Get weather response in XML format
Check whether sensor exists using "isSensorExists.xml"
Response either contains "InvalidParameterValue" or not
If response contains "InvalidParameterValue" — register the sensor
Print XML response from SOS
Insert data
Print XML response from SOS

Figure 24: Yahoo Fetcher Sequence Diagram.

For that particular component Waterfall development methodology would be enough since the simplicity and familiarity of the technology is at its finest.

4.3.2 Data Browser

DataBrowser will consist of blueprint, containing three panels and the main view area. Panels will represent the navigation and/or filtering options and remain the same across different pages, while the main view area will display the content of the particular page. One other panel in DataBrowser will be preserved for navigation in between the pages, which is simple and does not count as content display operation. There also should be a way to administrate the panels, meaning to change the name, image of the item, delete or add new one. Essential feature is to add integration from existing devices so that new items will be populated automatically within less than 24 hours. Adapter and Facade patterns will be used to deal with third-party components and sometimes to reduce the complexity within the application itself.

DataBrowser must follow basic Wicket style of inheriting the pages and communication with end-user via model-based programming paradigm. Everything, representing the logic and not directly related to GUI graphical user interface must be moved to a separate component and referenced via maven dependency. Essentially, DataBrowser should be nothing more complicated, than using SOS Integration, OpenLayers Integration and storing the model and user credentials in the session. The transition between the pages should be mounted to separate classes, while the panels should communicate via AJAX depending on the selected page. Figure 25 layouts the schematic design for DataBrowser.

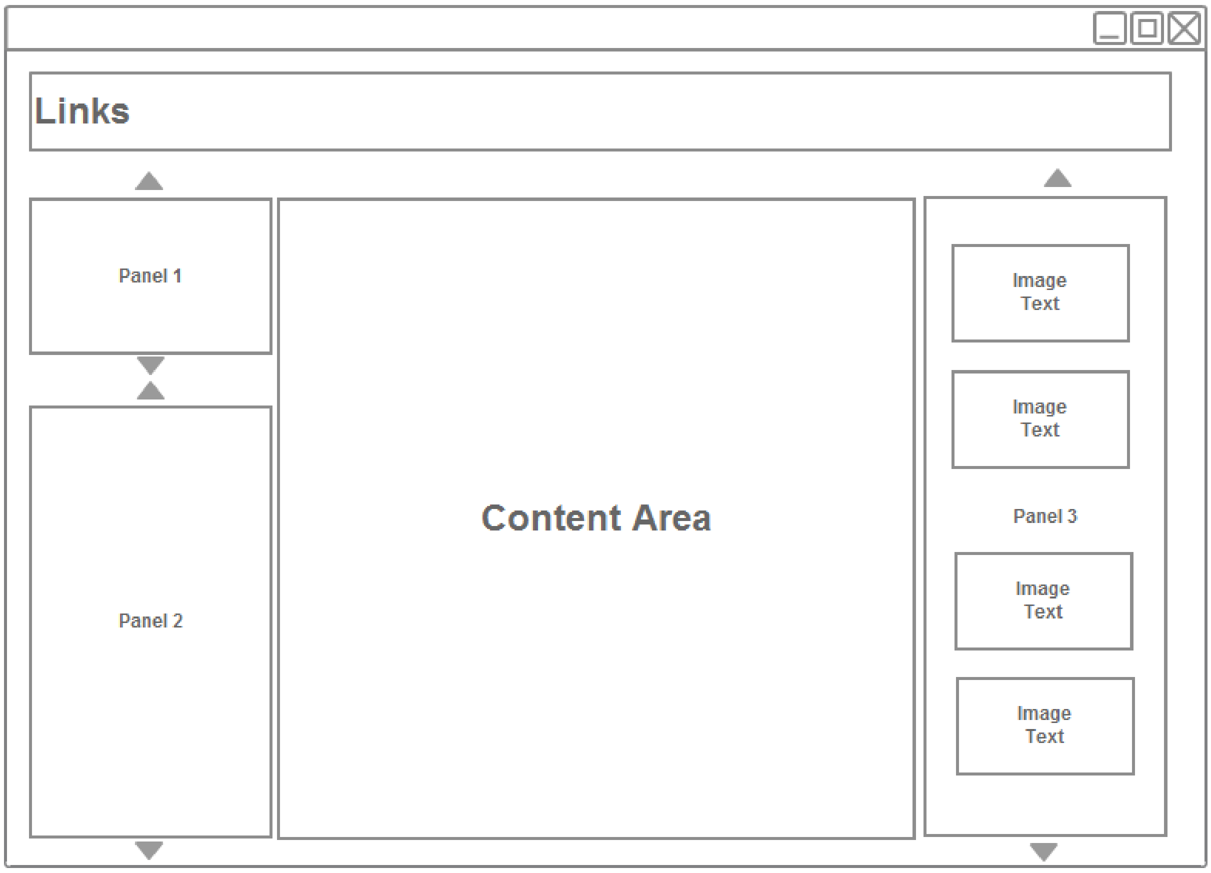


Figure 25: DataBrowser Schematic Design.

4.4 Software Implementation and Testing

Implementation will obviously take place in the world of Java EE using Wicket Framework, jQuery (which did not have integration by that time) manual insertion into html, XML, SOS and JDBC tricks.

Testing will be handled in Jetty application server environment, which has been chosen by Wicket's developers on the first place. Logs from there will be displayed right in the IDE, but logs from the PostGIS database operations will be displayed in the log files of the Apache Tomcat application server and mainly will be produced by 52°North SOS.

Wicket Framework, build from maven, comes with lightweight embedded Jetty application server for testing. [16] It allows starting the server and deploying the application by simple launching the Start.java file. [17] Also, Wicket does have its own testing class which relies on JUnit.

Because the requirement elicitation is never clear on the first place for such complex systems and also requirement functionality is never detailed enough to match the all the interfaces and technologies, system testing must be taken into account:

- **Black-box testing** — based on the requirements and answers the question "are we building the right product?" Does not reveal the system implementation. [5]
- **White-box testing** — based on implementation and answers the question "are we building the product right?" Potentially contains the un-documented functionality. [5]

4.4.1 Yahoo Fetcher

Following section explains the implementation of Yahoo Fetcher component, which is grabbing the data via Yahoo Weather XML API and puts them into PostGIS. This part consists of practical examples and pure code, therefore more information could be found in appendixes.

Constructor class implements the main logic of data flow diagram, presented earlier in architecture of the component. *[See Appendix 4 YahooFetcher main logic]*.

The communication with Yahoo Weather XML API uses the open protocol having a zip code of the city and optional parameter for getting temperature either in Celsius or in Kelvin. *[See Appendix 5 YahooFetcher fetch the weather data from YahooWeather API]*.

Incoming XML can be converted from the InputStream into string and saved as XML file. Also, sometimes the parameter "visibility" equals to NULL, which is not convenient in XSLT, therefore it must be replaced with zero before saving. *[See Appendix 6 YahooFetcher save the fetched data into XML]*.

Saved XML file with Yahoo Weather data can now be transformed using XSLT rules file resulting into a new XML, which is ready to be processed further. *[See Appendix 7 YahooFetcher transform the saved XML using XSLT rules]*.

XSLT transformation cannot take care of the sensor's name since it depends on the internal processes, therefore it is replaced separately. *[See Appendix 8 YahooFetcher additional data replacing in saved XML]*.

To check whether sensor already exists in the database or not, we can issue the describe sensor command. SOS will reply with invalid parameter value in case of no sensor presence and will outline the SensorML file if there is such. XML for describing sensor can be found in default templates of 52North documentation. *[See Appendix 9 YahooFetcher check whether sensor exists or not]*.

Lastly, gathered XML must be populated into PostGIS via SOS services. For debug purpose, function will also print the SOS response in the IDE log consol. *[See Appendix 10 YahooFetcher populate the XML via SOS]*.

Yahoo Weather data refreshes from 1 hour up to several days depending on the city, therefore is the component is running every couple of hours, it will always have the latest weather data. Such class can be called by city ZIP code, as following:

```
new WeatherFetcher("569806", address, sensor, addSensorTemplate,
addDataTemplate); // Mikkeli
```

4.4.2 Data Browser

In Wickets every AJAX behaviour component must be explicitly set into the updatable state by following member function [16]:

```
whatever.setOutputMarkupId(true);
```

To create an updatable via AJAX HTML container and specify the child component for Wicket page issue the following code [16]:

```
<span wicket:id="updatableAjax">
        <wicket:child />
</span>
```

This code defines the current HTML file as parent and hides the child implementation to the extended classes. The java class using such HTML must extend the Wicket's WebPage and be abstract. Meanwhile, the child HTML file will gain to clause: extend and head. Head is used for whatever linkage files the HTML file was supposed to reference in the head section, while extend will be replaced with child clause at the rendering time on the upper level. Java class of child page is derived from the parent class. It is done in a way, that parent abstract class has AJAX containers and adds components to the page itself, but the derived classes add components to the containers, getting the reference from the parent class. Consider following example:

```
<wicket:head>
        <link rel="stylesheet" href="style.css" type="text/css" />
</wicket:head>
<wicket:extend>
        A child has been born!
</wicket:extend>
```

Another option to extend and simplify the document structure is to use panels instead of child-parent pair. With panels, they can be anything, which is better to keep outside of the document scope, while child always have parent and parent has to have some child. Java class extends the panel, or the implementation of the panel in case of using OpenLayers. HTML for the panel is fairly simple:

```
<wicket:panel>
	Any single word here.
</wicket:panel>
```

Panels must be created in Wicket inherited style for HTML pages. Also, AJAX must be used in the panels to prevent the server from constant refreshing the same exact data and keep the user selections on the same place. Because Wicket does not have good integration with jQuery (the one I found was simply overcomplicated due to fact that you not only have to create a jQuery code on your own, but also the java code as well. There is not any purpose or advantage of doing that, instead it is much simpler to just write direct jQuery inside of HTML and it will still hold the Wicket style of not putting HTML inside of java) I decided to bind the HTML containers with hidden ID inputs inside of the panel and pass it to the jQuery.

The trick is so, that each item in the panel is essentially an HTML form. At the time of rendering each item is supplied with hidden input field with id. Such id will be used as a reference to the SOS integration. Panel will populate the appropriate image (if does not exists — use default image) and name to the item, but mostly important — the AJAX link which must perform an actions, dependent on what page the user is viewing. For example, for the MapPage the user should be able to filter the markers when clicking on the items, meanwhile on the ListPage the click action on the item must result into change of the table view. On GraphPage, clicking the item essentially reloads the page in contrast with other pages, where communication is done via AJAX. Sometimes, panels must be dependent not only based on the viewed page, but also on each other, for example selections on one panel will filter the items on the other. Also, panel may allow multiple selections (checkbox) or only single one selection (radio button). It is important to keep track on which items were selected and which were not. Wicket does not have any embedded function for that, so I decided to use jQuery class here. Basically, each item has the state true or false inside of the Wicket, and at the time of rendering I can add different classes to the HTML containers based on such states. jQuery will take the class, which is “active” or “passive” and toggle the style for each of them. Because the states are held on Wicket side it is possible to preserve the states and the view for the end user in correct form.

The distinguish behaviour for each panel based on the page can be archived by the fact, that each page is a different object, derived from the same class. Therefore, decision path for the panel's actions and selection as well as link selection cuts to:

```
if (page instanceof MapPage)
        …
if (page instanceof ListPage)
        …
if (page instanceof GraphPage)
        …
```

One issue with panels is that they are scrollable. That means that in case of travelling from one page to another the state of the items is easy to keep, but how keeping the position of the last clicked item? There could be more than 10 of them and user does not want to search for the common place all the time. The answer lays in the jQuery jCaroUsel component options. There is an option to start at any random item, but the referencing to such item must be done via separate Wicket component. The problem there is that Wicket always works with HTML containers if not specified otherwise. To pass the pure string into JavaScript code developer need to explicitly disable the escape modelling of such string:

```
new Label("jsContainer", jsContainer).setEscapeModelStrings(false);
```

All the panels and also the table in ListPage are using Observer pattern, which is called List-View in Wicket. Such pattern implements the idea of changing the model on the fly, resulting into changing the view. Dynamic nature of Observer is important, since panels are updatable via AJAX. Mediator pattern will take care of communication in between the panels to reduce the dependency. Consider the following implementation of loadable model:

```
IModel<Vector<String>> repeatingList =
        new LoadableDetachableModel<Vector<String>>() {
    private static final long serialVersionUID = 1L;

    @Override
    protected Vector<String> load() {
        return new Vector<String>();
    }
};
```

Such code creates a Wicket model with model, consuming the vector of strings. It overrides the load function to create the object from any source developers might have. Next piece of code takes the model; bind it to the HTML container and overrides the populate function which feeds the single object of the model:

```
ListView<String> repeatingView =
        new ListView<String>("repeatingViewTable", repeatingList) {
    private static final long serialVersionUID = 1L;

    @Override
    protected void populateItem(ListItem<String> item) {
        String s = (String) item.getModelObject();
        item.add(new Label("title", s));
    }
};
```

The idea is so, that LoadableDetachedModel is a complex model, fetching itself based on some business logic, while the ListView is pure html-oriented component, taking every single object from the vector of the model and populating it to the document.

Pages themselves must be nearly identical; therefore I will create a MainPage which will be an abstract constructor for every other page. It will create the structure for panels in Wicket HTML style as well as reference to css/JavaScript files, change the title of the page and provide a reference to the session resources.

Another important issue is to store the session across the web application. In case of simple servlet query, I will end up fetching the entire database every time I change the page, which could possible take up to several minutes. Instead, I can fetch it for the first time and keep it internally, modifying if needed. Fortunately, Wicket does have a session class, which in combine with main application may contain any data structure. Such data structure can be referenced from any page because of the inheritance. Session is using the expensive operation to the SOS integration model — let it utilize the Proxy pattern to reduce the cost of fetching the items, which are outside of the scope of interest.

AdministrationPage will allow database manipulation in CRUD style. It is important to know, that in Wickets the main application as well as the session itself are derived from the base class. In case of using authentication and authorisation base classes become different as well. Those new classes will provide new functions to override, which will be responsible for singing up and out, getting roles and starting new session. Administration feature is very sensitive and require only one instance of admin user across the application. Let the Singleton pattern deal with it.

The authentication session can be checked from the session class in overridden function:

```
@Override
public boolean authenticate(final String username,
                                       final String password) {
        return new Admin(username, password).isAuthenticated();
}
```

Session also provides the array of roles, available for authenticated admin:

```
@Override
public Roles getRoles() {
        return admin.getRoles();
}
```

Such roles can be used as annotation on the class or panel. Checking can also be done manually, since the usage of annotations is not available for functions and member variables. Consider the example, where class can be accessed by the users with any of two roles:

```
@AuthorizeInstantiation({"developer", "manager"})
public class CompanyPage {}
```

Other option is not only allowing access, but specifies the actions. Here, the page will be loaded for any role, bet component rendering will succeed only for the role “developer”:

```
@AuthorizeAction(action = "RENDER", roles = "developer")
public class CompanyPage {}
```

Administrator page will take advantage of JDBC; therefore I should provide an XML configuration file with connection options for the database. On the long run it will be used to re-link to the production server.

Wicket folder consist of java files, webapp, which holds the client code (html/css/JavaScript and images) and resources, which are used to reference from the java files, because java cannot link to the standard webapp folder.

One distinguished example is the BigGraphPage which essentially is expanded to the full screen GraphPage. It is interesting, that Even though BigGraphPage is not derived from the IndexPage nad does not inherit anything but standard BasePage, it still has access to all capabilities of the application.

Another issue with both GraphPage and BigGraphPage is that they are using OpenFlashChart, which obviously based on flash, meaning that page has to be refreshed since not build-in AJAX capabilities are exist. Also, OFC has to use resource folder and be bind to the URL explicitly. It can be done in the main application file, along with the ListPage requirement, concerning the parameter passing. The page refreshing, however, can be done via AJAX as well, but it is a little bit tricky and still does the common refreshing page behaviour [16]:

```
new AjaxFallbackLink<Object>("refresh") {
        @Override
        public void onClick(AjaxRequestTarget target) {
                target.appendJavascript("window.location.reload()");
        }
}
```

The mounting of a page to the particular name can be done in the main application class [16]:

```
@Override
protected void init() {
        super.init();
        mountBookmarkablePage("graph", GraphPage.class);
}
```

ListPage was the tricky one, because Wicket possesses the table component, but it failed to impress due to its complexity and lack of flexibility. Instead, I re-implemented it in pure

HTML table for Wicket side and transform it into a view with filtering and exportable features on the client side with help of jQuery.

Non-functional requirements states, that user interface should be modern. Rounded corners are not displayed in IE being configured via css. The trick is so, that IE need to have explicit DOCTYPE for each HTML document. But if I do so, the map will disappear from the rest of the browsers due to the GMaps dislike of DOCTYPE. Solution here is to manually hardcode the DOCTYPE appearing in certain browsers:

```
<!--[if IE]>
<!DOCTYPE HTML
     PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
     "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<![endif]-->
```

4.5 Software Deployment and Maintenance

As it was mentioned before, the Observis Oy provides PaaS as well, meaning that deployment occurs on their own server eliminating the cost of outsourcing. Apache Tomcat was used as an application server, hosting both 52 North SOS and DataBrowser as WAR (Web Application Archives) files. Building the WAR file can be archived by the use of in-built Eclipse IDE Maven 2 plug-in. All Java classes were commented in JavaDocs style with annotations for input/output variables.

The prototype is a subject to be build, deployed, tested, evaluated and being rebuild until the acceptance criteria will take place. [4] Maintenance is taken into consideration only in form of future development and following the Wicket style for Data Browser and component style architecture for the whole prototype.

There was one issue with the Safari browser working under Mac OS X operating system (Win X family shows the ability to operate perfectly). It was caused by the use of GMaps components, where map on the MapPage fail to appear. The solution was simple usage of “**<span>**” clause instead of “**<div>**”, but it took a while to figure that out.

The other issue is once again — the GMaps. This time it failed to display the map due to the jsessionid hash key in the URL provided by Wicket app at the beginning of any session.

GMaps API KEY must be generated for the particular URL which does not contain such hash. It is not possible to predict the jsessionid key in advance because every time it is different and unique across the application server. The solution is to manually clean up the hash in URL after the start-up of the application, but before the redirection to the MapPage and displaying the map. In main application java file override the following function: *[See Appendix 4.5 Prevent the jsessionid key in URL for displaying the GMaps]*.

Couple of times Apache Tomcat saved the session from the previously deleted application resulting into the memory leak. Such problem was eliminated by restarting the application server. Session life time was set to 30 min by default, preventing the DataBrowser from re-fetching the data during inactive time.

All the dependencies on local machine path were handled by loose coupling features, which are XML configuration files. Because of that, one undocumented capability is to deploy the DataBrowser on one server, but force it to fetch the SOS database data from the other server. It was really helpful in testing the working time on DataBrowser from production server, which fetches the data from the local testing machine.

By default, Wicket is started in the testing mode, providing features for AJAX message tracing and error reporting. To set the application into production mode, giving the application more performance by reducing the error catching capabilities, developer must turn the trigger on in the main application java file [16]:

```
/**
 * Setup application mode (DEVELOPMENT || DEPLOYMENT)
 */
@Override
public String getConfigurationType() {
  return DEPLOYMENT;
}
```

4.5.1 User Interface of the Prototype

In the following section I will present how the DataBrowser looks and what functionality it has.

GraphPage lays out data in flash format. Default and the most common is a line chart, which can take multiple entries for the lines and differentiate them by given aspect (Figure 26).

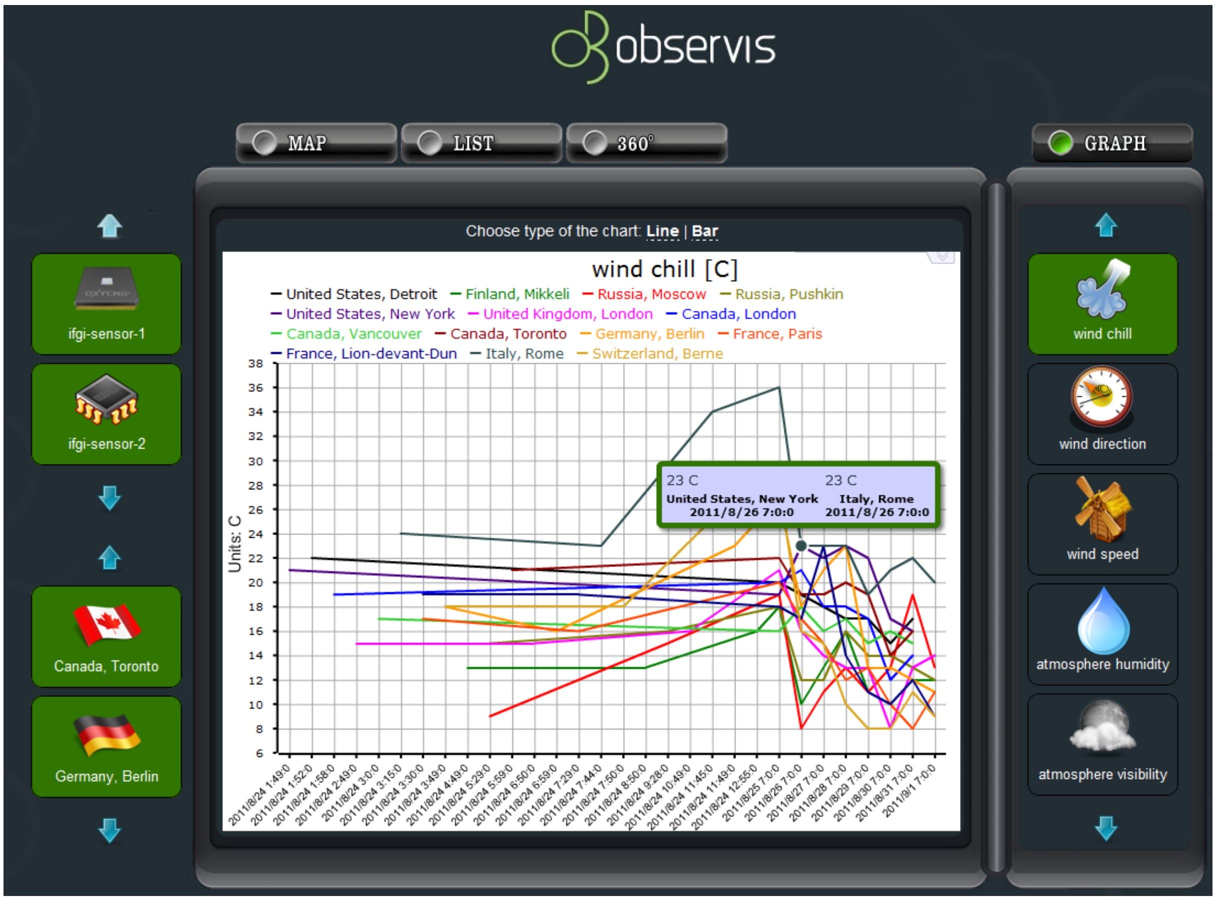


Figure 26: DataBrower / GraphPage / Line chart.

The graphic consist of unit for y-axis and time for x-axis. Each time YahooFetcher component fetches the weather data; it gets registered in the system and attached to the certain condition and time. The graph populates by inserting the points and connecting them by lines. In case of missing time-points lines will assume the value by calculating an average in between of two nearest points. This usually happens because different cities have value for different time-stamp but each timestamp has to be on the graph. In case of having the values for the same timestamp for more than one city, the OFC has nice feature to popup the dialog for both of them with additional information. The last type of the chart is a pie chart, which represents values not based on one, but based on all selected cities (Figure 27). The flash also allows to save the view screen in PNG format or to expand the view into new window making it bigger.

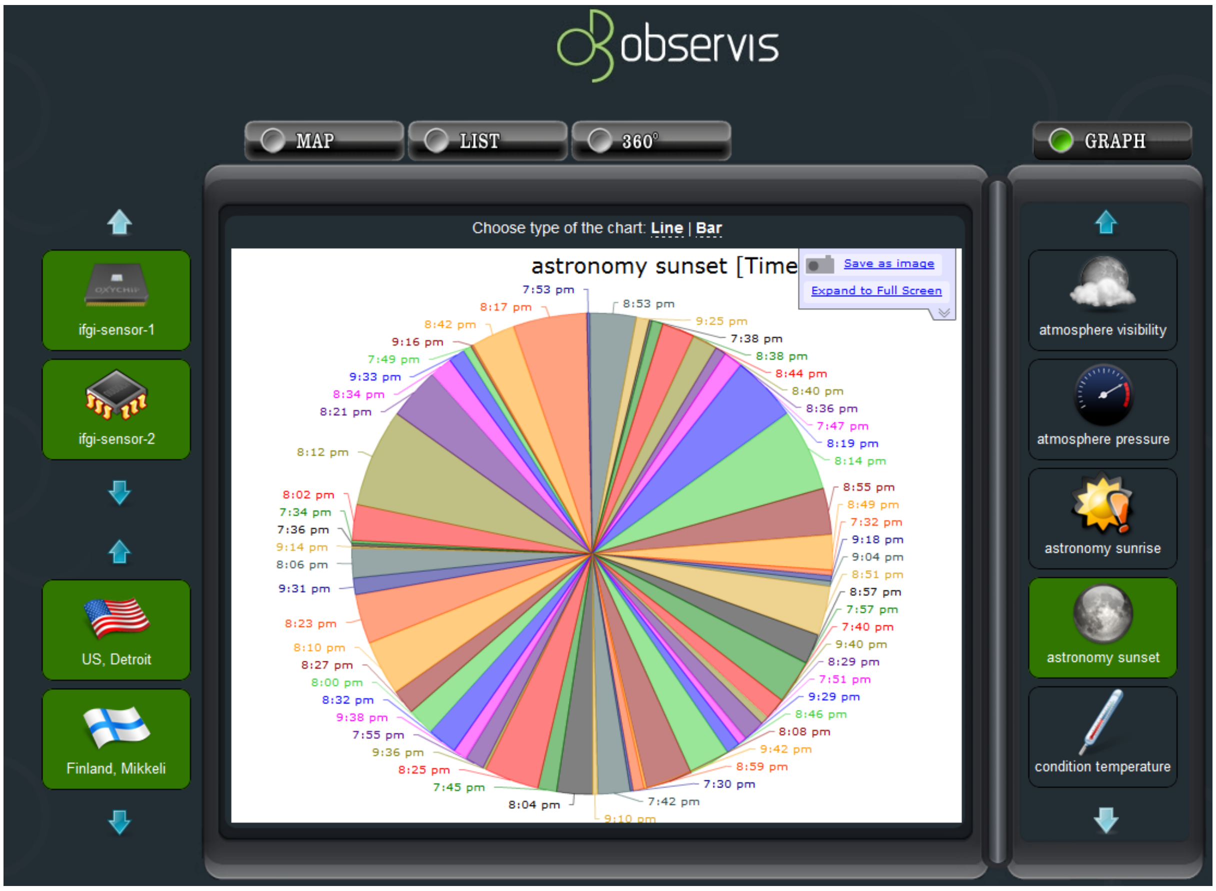
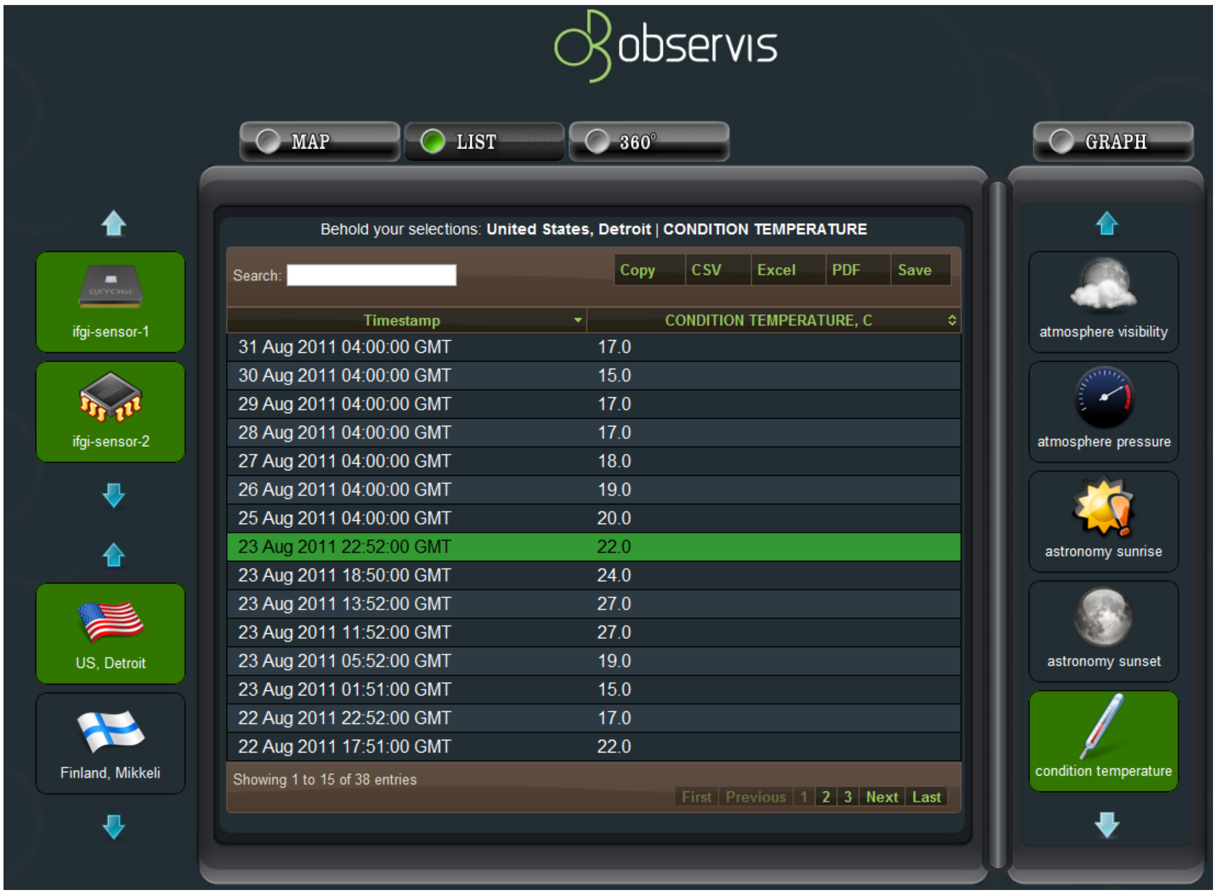


Figure 27: DataBrower / GraphPage / Pie chart.

Unlike GraphPage, ListPage will provide an ability to view data in table format with handy features, such as column sorting, searching for string presence in both of the columns, listing up to 15 records per page (Figure 28). Besides that, third-party framework based on jQuery power the list with exporting features in CSV (Comma Separated Value), Excel or PDF formats. It is even possible to save the data to clipboard by using “Copy” button. This view allows only one-to-one selection between city and weather aspect, for example “Detroit” and “temperature”. Firstly, the content view was done via default table component coming from Wicket, but because of its complexity and reduced flexibility for a release I decided to switch to the pure jQuery style table with outsourced exporting features. Such solution even escaped from violating the golden rule of Wicket architectural style — split HTML and java implementation. The problem with Wicket table also was so, that every time it lists the pages back and forth it fetches the data from back end java, which is a waste of resources. JavaScript implementation simply fetches all the data once and populates them into simple HTML table with no hard coding involved and the page listing features are handled by script in a way of updating the table.



Behold your selections: **United States, Detroit | CONDITION TEMPERATURE**

Search:

Timestamp	CONDITION TEMPERATURE, C
31 Aug 2011 04:00:00 GMT	17.0
30 Aug 2011 04:00:00 GMT	15.0
29 Aug 2011 04:00:00 GMT	17.0
28 Aug 2011 04:00:00 GMT	17.0
27 Aug 2011 04:00:00 GMT	18.0
26 Aug 2011 04:00:00 GMT	19.0
25 Aug 2011 04:00:00 GMT	20.0
23 Aug 2011 22:52:00 GMT	22.0
23 Aug 2011 18:50:00 GMT	24.0
23 Aug 2011 13:52:00 GMT	27.0
23 Aug 2011 11:52:00 GMT	27.0
23 Aug 2011 05:52:00 GMT	19.0
23 Aug 2011 01:51:00 GMT	15.0
22 Aug 2011 22:52:00 GMT	17.0
22 Aug 2011 17:51:00 GMT	22.0

Showing 1 to 15 of 38 entries

Figure 28: DataBrower / ListPage.

MapPage was one of the key points in data layout (Figure 29). Currently, it supports the GMaps and OpenStreetMaps, but much more integrations are coming in latest release. Also, the MapPage causes the most amounts of errors during the deployment and implementation phases. Two possibilities exists while displaying the point — there could be only one weather aspect or more than one with the same latitude and longitude on the map. One aspect represents itself with icon, but more than one were hard coded in a way that top icon is always the icon provided in GIF format from yahoo weather API and shows the expected weather forecast as picture. Because OpenLayers allows only one layer for each icon it is essential not to put them over each other. Spreading icons into separate layers is possible, but requires more complicated code and practically creates a mess in business logic. The weather icon from Yahoo Weather must always stay on top. The problem was so, that every time the user selects the city or weather aspect, map view gets filtered out, which is perfectly fine, but once the user filters them back on the map, new icons overlay the previous one. The solution was so, that each time user filters the markers, map view redraws every single one in a way that it follows the "weather icon on the top" rule. Such solution is resource consuming, but at the same time it is the only feasible one.

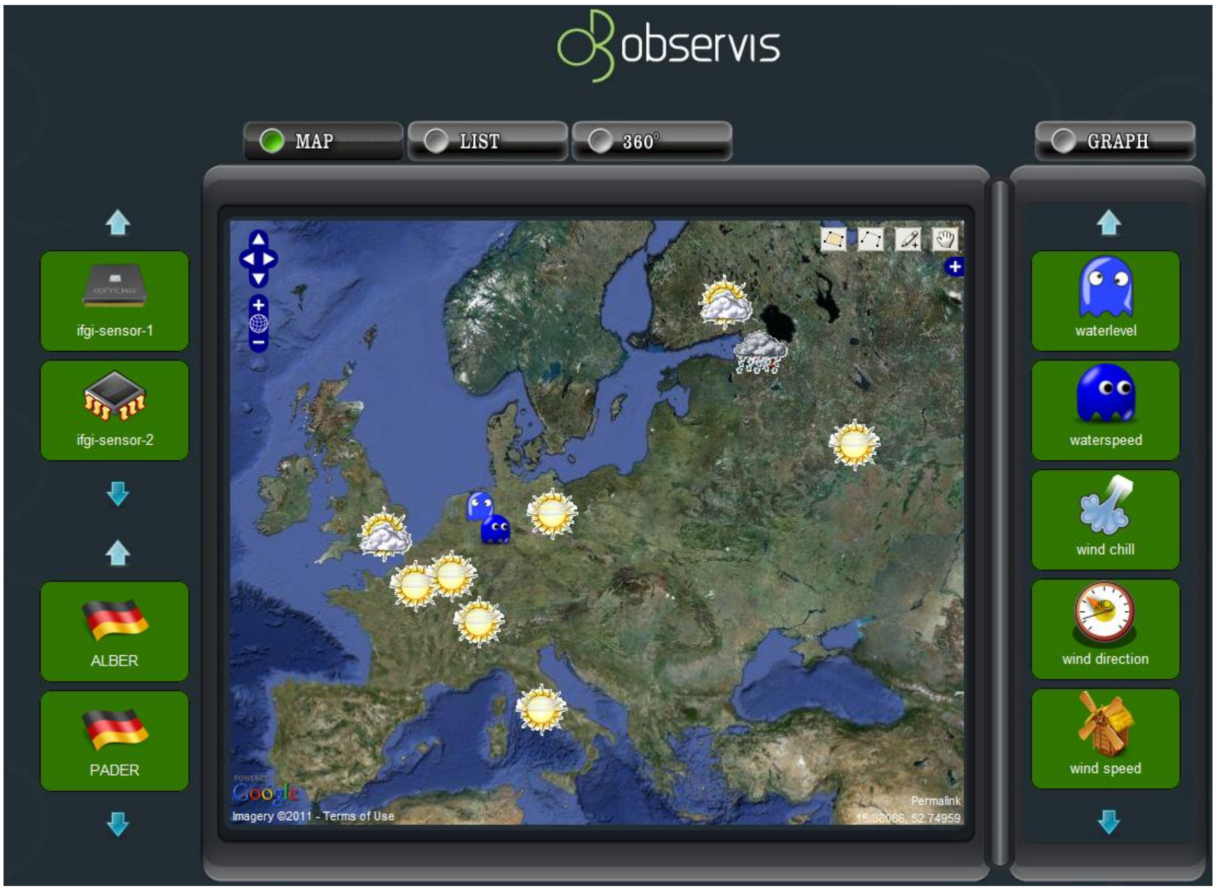


Figure 29: DataBrower / MapPage / Europe.

When the user zooms into such location, he can see all the icons around the real position (Figure 30). Cities on the map can be filtered on the panel side as well as weather aspects from yahoo weather. Because the YahooFetcher was put into use to fetch the data every day, it was an interesting experience to see the clouds and fog moving across the Europe while North America stood in “night” transition. User can get more information from the weather if he clicks on the corresponding icon, resulting into pop-up appearance. Such pop-up contains the current situation of the chosen weather aspect as well as the links to ListPage and GraphPage (Figure 31).

Each panel is scrollable under jCaroUsel framework coming from jQuery. Each panel is also has different functionality depending on the selected page, for example on GraphPage it allows multiple selection for cities, but only one for weather aspect, while for ListPage it is always one-to-one. MapPage also filters content by sensors, meaning that it not only filters the view area, but also the panels. Website itself has the administration page which is not shown here for security purpose, but can be only accessed by typing the URL in address bar. Login page checks the authorization of the person and based on that shows the managing features.

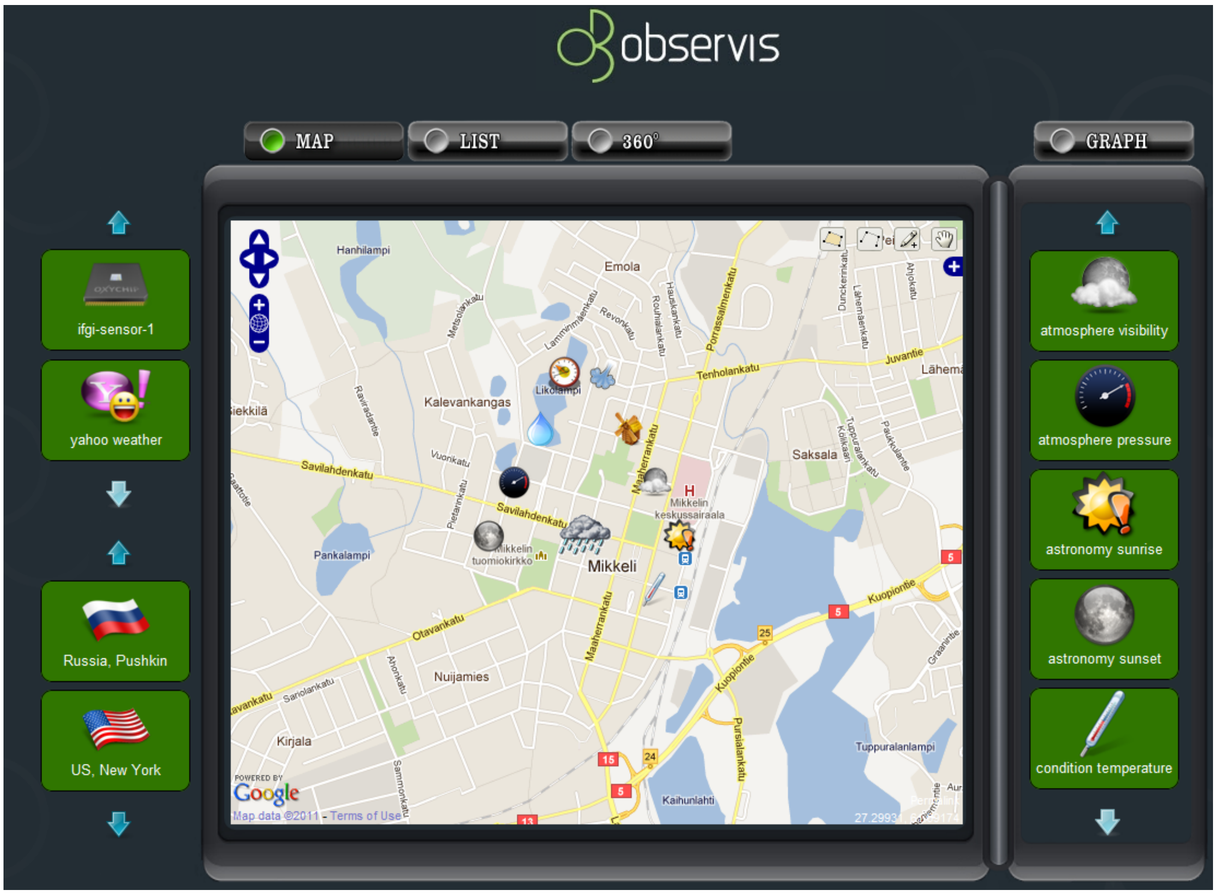
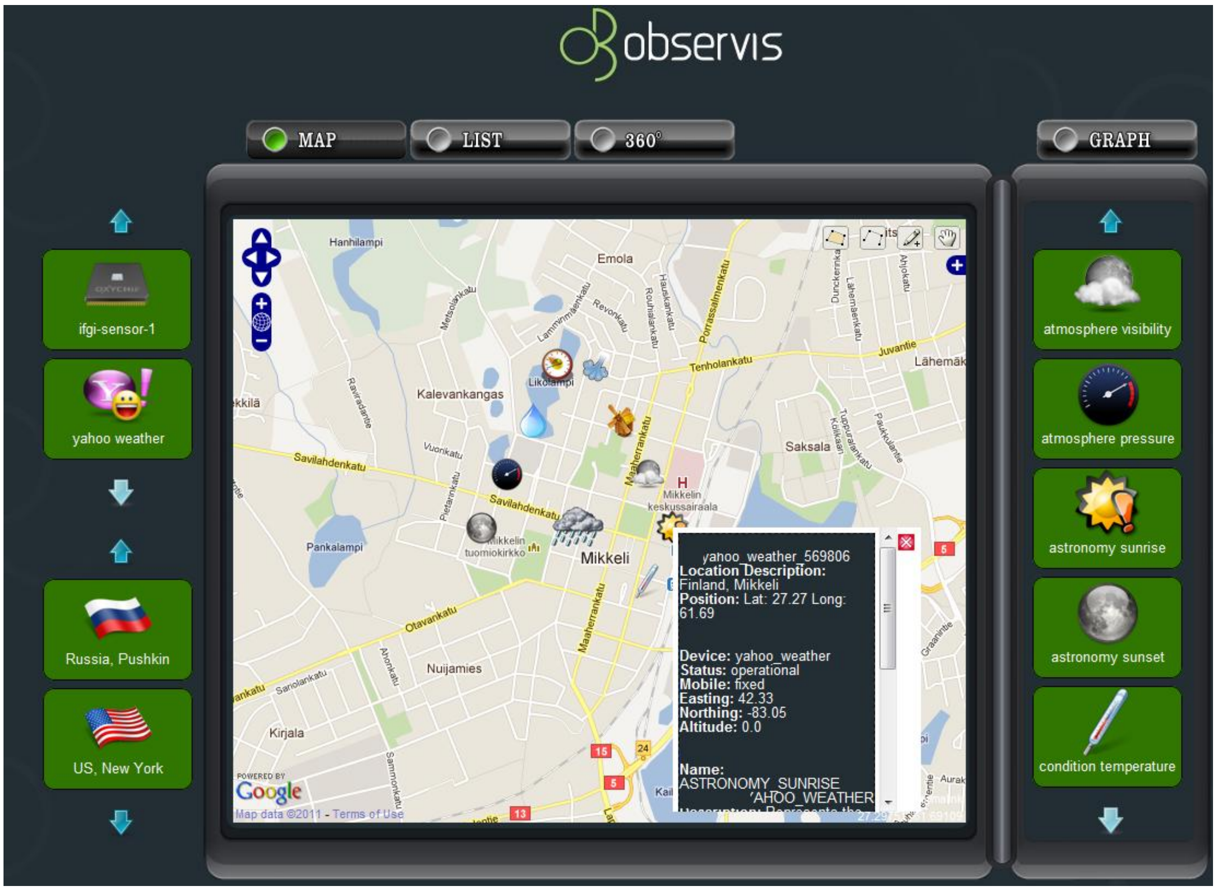


Figure 30: DataBrower / MapPage / Mikkeli.



yahoo_weather_569806
Location Description: Finland, Mikkeli
Position: Lat: 27.27 Long: 61.69

Device: yahoo_weather
Status: operational
Mobile: fixed
Easting: 42.33
Northing: -83.05
Altitude: 0.0

Name: ASTRONOMY_SUNRISE
'AHOO_WEATHER

Figure 31: DataBrower / MapPage / Mikkeli Pop-up.

5 CONCLUSION

By using throw-away prototype methodology I proved the concept of Observis Platform, investigated functional possibilities, limitations of programming language framework and discovered the third-party software implementation. Understanding of our own problem domain was supplied with more clear view of spatial database scheme.

At first I discussed general enterprise architecture, its applications, patterns and different models. I concentrated mostly on problem-related topics, such as Service-Oriented and Multi-Tier Architectures, which are the most popular among web-based development process. Finally, I concluded the theory part with introducing the concepts of software engineering components, which differentiate simple programming from software architecture development.

Second part of thesis covers practical implementation of our project. In this case example I went throw whole software development process, applying knowledge, gathered in the theory part. I started from the information gathering and deciding on functional/non-functional requirements and its analysis. That knowledge was used for creating use case diagrams and use case descriptions, defining the scope of our project. Having clear use cases I was able to do the system design and further more understand the event-flow and control-flow activities of our application. Once I had enough of design, implementation and testing of the system took its place. Each cutting edge version of software was published on the internal company structure and presented for visualization of the results.

Prototype has been divided into three components: Yahoo Fetcher is relatively small and its only purpose is to fulfil the spatial database with data coming from the Yahoo Weather API in XML format; Data Browser is the largest of all since it serves as presentation and administration tool, operating with database information, gathered by Yahoo Weather component; SOS Model takes care of core data-retrieving functionality and lays in between the Data Browser and spatial database management system.

Because I was using rapid application development methodology, I was constantly iterating in cycle of gathering requirements, design, implementation and testing of the prototype. Each time I thought that I implemented very last thing and exhaust every last possibility on the testing stage, I came across to the presentation and discovered that there is plenty more things to do, therefore it’s back to the requirement elicitation. This way turned out to be the best method, because problem domain was unknown and requirements were unclear. At the end of the project I learned more about our own system and prototype became a predecessor for future Observis Platform, which will eliminate lots of previous mistakes and start new line of the development from the scratch having better understanding of the solution domain.

With that, my Final Thesis concludes the modern software development process at its best manner combining theoretical knowledge and converting them into practical-oriented solution. Having such a prototype, Observis Oy will be able to further more develop the system and implement Observis Platform, which will make our life easier.

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APPENDICES

Appendix 1 OpenLayers JavaScript with map and marker layout

```
<script type="text/javascript"><!--/*--><![CDATA[/*><!--*/
// Dummy Map Object
var map;

/**
* Initialize Map Object onLoad()
*/
function init() {
/**
* Map
*/
  map = new OpenLayers.Map('map');
        layer = new OpenLayers.Layer.WMS( "OpenLayers WMS",
                "http://vmap0.tiles.osgeo.org/wms/vmap0", {layers: 'basic'}
);

   var labelLayer = new OpenLayers.Layer.Vector("Simple Geometry", {
                  styleMap: new OpenLayers.StyleMap({'default':{
                                  strokeColor: "${color}",
                                  strokeOpacity: 1,
                                  strokeWidth: 3,
                                  fillColor: "${color}",
                                  fillOpacity: 0.5,
                                  pointRadius: 20,
                                  pointerEvents: "visiblePainted",
                                  // label with \n linebreaks
                                  label : "${name}",
                                  fontSize: "14px",
                                  fontWeight: "bold",
                                  fontFamily: "Arial",
                                  labelYOffset: "-30"
                  }}),
                  renderers:
OpenLayers.Util.getParameters(window.location.href).renderer
   });

   // Add Image and Label Layers to the Map
   map.addLayers([labelLayer, layer]);

   // Setup Map
   map.zoomToMaxExtent();
   map.setCenter(new OpenLayers.LonLat(27.2721715, 61.6885233), 6);

/**
* Markers
*/
```

```
   var markers = new OpenLayers.Layer.Markers("Markers");
   map.addLayer(markers);

   var markerClick = function (evt) {
                  if (this.popup == null) {
                                 this.popup =
this.createPopup(this.closeBox);
                                 map.addPopup(this.popup);
                                 this.popup.show();
                  } else {
                                 this.popup.toggle();
                  }

                  currentPopup = this.popup;
                  OpenLayers.Event.stop(evt);
   };

/**
* Marker 1 Begin
*/
   var feature = new OpenLayers.Feature(markers, new
OpenLayers.LonLat(27.2721715, 61.6885233));
   feature.closeBox = true;
   feature.data.popupContentHTML = '<img
src="http://www.jfree.org/jfreechart/images/PriceVolumeDemo1.png" />';
   feature.data.icon = new
OpenLayers.Icon('http://icons.iconarchive.com/icons/arrioch/halloween/64/ra
dioactive-icon.png',



                                                                                              );
   feature.data.overflow = "auto";
   feature.popupClass = OpenLayers.Class(OpenLayers.Popup.FramedCloud, {
                  'autoSize': true
   });

   var marker = feature.createMarker();
   marker.events.register("mousedown", feature, markerClick);

   var labelFeature = new OpenLayers.Feature.Vector(new
OpenLayers.Geometry.Point(27.2721715, 61.6885233));
   labelFeature.attributes = {
                  name: "Scary Face",
                  color: "blue"
   };

/**
* Marker 1 Finish
*/
   markers.addMarker(marker);

   // Add Labels and glowing sphere around the Marker
   labelLayer.addFeatures([labelFeature]);
```

```
}
/*-->]]>*/</script>
```

Appendix 2 Cleveland Volcano SensorML description

```
<?xml version="1.0" encoding="UTF-8"?>
<sml:SensorML version="1.0.1"
  xmlns:sml=”http://www.opengis.net/SensorML”
  xmlns:swe="http://www.opengis.net/swe/1.0.1">
  <sml:member>
    <sml:System xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">

      <!--sml:identification element must contain the ID of the sensor -->
      <sml:identification>
        <sml:IdentifierList>
          <sml:identifier>
            <sml:Term definition="urn:ogc:def:identifier:OGC:uniqueID">

<sml:value>urn:ogc:object:feature:Sensor:IFGI:ClevelandVolcano<sml:value>
            </sml:Term>
          </sml:identifier>
        </sml:IdentifierList>
      </sml:identification>

      <!-- sml:capabilities element has to contain status and mobility in-
formation -->
      <sml:capabilities>
        <swe:SimpleDataRecord>
          <!-- status indicates, whether sensor is collecting data at the
moment
            (true) or not (false) -->
          <swe:field name="status">
            <swe:Boolean>
              <swe:value>true</swe:value>
            </swe:Boolean>
          </swe:field>
        </swe:SimpleDataRecord>
      </sml:capabilities>

      <!-- last measured position of sensor -->
      <sml:position name="sensorPosition">
        <swe:Position referenceFrame="urn:ogc:def:crs:EPSG::4326">
          <swe:location>
            <swe:Vector gml:id="STATION_LOCATION">
              <swe:coordinate name="easting">
                <swe:Quantity>
                  <swe:uom code="degree" />
                  <swe:value>45.0<swe:value>
                </swe:Quantity>
              </swe:coordinate>
```

```
                <swe:coordinate name="northing">
                  <swe:Quantity>
                    <swe:uom code="degree" />
                    <swe:value>45.0</swe:value>
                  </swe:Quantity>
                </swe:coordinate>
                <swe:coordinate name="altitude">
                  <swe:Quantity>
                    <swe:uom code="m" />
                    <swe:value>1000</swe:value>
                  </swe:Quantity>
                </swe:coordinate>
              </swe:Vector>
            </swe:location>
          </swe:Position>
        </sml:position>

        <!-- list containing the input phenomena for this sensor system -->
        <sml:inputs>
          <sml:InputList>
          <sml:input name="time">
            <swe:ObservableProperty defini-
tion="urn:ogc:def:phenomenon:OGC:1.0.30:time" />
          </sml:input>
          </sml:InputList>
        </sml:inputs>

        <!-- list containing the output phenomena of this sensor system -->
        <sml:outputs>
          <sml:OutputList>
          <sml:output name="ash">
            <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.0.30:ash">
              <gml:metaDataProperty>
                <offering>
                  <id>ash</id>
                  <name>Amount of ash thrown out of the pipe</name>
                </offering>
              </gml:metaDataProperty>
              <swe:uom code="units" />
            </swe:Quantity>
          </sml:output>
          <sml:output name="lava">
            <swe:Quantity defini-
tion="urn:ogc:def:phenomenon:OGC:1.0.30:lava">
              <gml:metaDataProperty>
                <offering>
                  <id>lava</id>
                  <name>Density of lava thrown out of the pipe </name>
                </offering>
              </gml:metaDataProperty>
              <swe:uom code="kg/m3" />
            </swe:Quantity>
          </sml:output>
          </sml:OutputList>
        </sml:outputs>

      </sml:System>
    </sml:member>
  </sml:SensorML>
```

Appendix 3 Prevent the jsessionid key in URL for displaying the GMaps

```
  /**
   * Prevent jsessionid for GMaps API Key display
   */
  @Override
  protected WebResponse newWebResponse(HttpServletResponse servletResponse)
{
    return new BufferedWebResponse(servletResponse) {

      @Override
      public CharSequence encodeURL(final CharSequence url) {
         final CharSequence encodeURL = super.encodeURL(url);

         String s = encodeURL.toString();
         int i = 0;

         if (s.indexOf("jsessionid=") >= 0) {
           i = s.indexOf("?");
           if (i >= 0) {
             return encodeURL.subSequence(i, encodeURL.length());
           } else {
             return encodeURL;
           }
         } else {
           return encodeURL;
         }
      }

      @Override
       public void sendRedirect(String url) throws IOException {
        CharSequence encodeURL = super.encodeURL(url);

         String s = encodeURL.toString();
         int i = 0;

         if (s.indexOf("jsessionid=") >= 0) {
           i = s.indexOf("?");
           if (i >= 0) {
             encodeURL = encodeURL.subSequence(i, encodeURL.length());
           }
         }

         getHttpServletResponse().sendRedirect((String) encodeURL);
      }

    };
  }
```

Appendix 4 YahooFetcher main logic

```
  /**
   * Constructor takes zip code of the city (ID) and SOS address, then
   * fetches weather date form yahoo server and stores it in
"YahooWeather.xml", then
   * sends sensor describe request to SOS: if response is Invalid - add
sensor, if not - add data.
   *
   * @param ID - zip code of the city according to yahoo weather api.
   * @param sosAddress - address of sos service
   * @param sensor - name of the sensor
   * @param addSensorTemplate - sensor xsl template
   * @param addDataTemplate - data xsl template
   */
  public WeatherFetcher(String ID, String sosAddress, String sensor,
               String addSensorTemplate, String addDataTemplate) {
    this.setAddress(sosAddress);
    this.setSensor(sensor);
    this.setAddSensorTemplate(addSensorTemplate);
    this.setAddDataTemplate(addDataTemplate);

    // Create YahooWeather.xml from query
    try {
      SaveWeatherXML(FetchWeather(ID), "YahooWeather.xml");
    } catch (MalformedURLException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }

    // Check whether sensor already exists or not
    if (!isSensorExists("isSensorExists.xml", "$SENSOR_ID$")) {
      FormXML("YahooWeather.xml", this.getAddSensorTemplate(),
                                                "AddSensor.xml");
      PopulateXML(ReplaceXML("AddSensor.xml", "$SENSOR_ID$"));
    }

    // Add data for the sensor
    FormXML("YahooWeather.xml", this.getAddDataTemplate(),
                                                "AddData.xml");
    PopulateXML(ReplaceXML("AddData.xml",
                        SENSOR_ID$").replace("$ID$", ID));
  }
```

Appendix 5 YahooFetcher fetch the weather data from YahooWeather API

```
  /**
   * Connects to the Yahoo Weather service and fetches the xml data based
on ID
   *
   * @param ID - zip code of the city according to yahoo weather api.
   * @return InputStream - retrieved data from Yahoo Weather service
   * @throws MalformedURLException
   * @throws IOException
   */
  public InputStream FetchWeather(String ID)
                       throws MalformedURLException, IOException {
      return new URL(
            "http://weather.yahooapis.com/forecastrss?w=" + ID + "&u=c"
          ).openConnection().getInputStream();
  }
```

Appendix 6 YahooFetcher save the fetched data into XML

```
  /**
   * Saves fetched data into yahooXMLFile param
   *
   * @param is - InputStream from Yahoo Weather service
   * @param yahooXMLFile - name of the destination file
   */
  public void SaveWeatherXML(InputStream is, String yahooXMLFile) {
      Writer writer = new StringWriter();

        char[] buffer = new char[1024];
        try {
            Reader reader = new BufferedReader(
                                    new InputStreamReader(is, "UTF-8"));

            int n;
            while ((n = reader.read(buffer)) != -1) {
                writer.write(buffer, 0, n);
            }

            is.close();
        } catch (Exception e) {
      e.printStackTrace();
    }

      File f = new File(yahooXMLFile);
      FileWriter fw = null;
```

```
        // YahooWeather sometimes contains null value for visibility field
        // Inserting null into SOS fails the query to execute
        try {
        fw = new FileWriter(f);
        fw.write(writer.toString().replace("visibility=\"\"",
                                            "visibility=\"0\""));
        fw.close();
      } catch (IOException e1) {
        e1.printStackTrace();
      }
    }
```

Appendix 7 YahooFetcher transform the saved XML using XSLT rules

```
  /**
   * Transforms yahooXMLFile based on the templateXML rules and stores re-
sult in outputXML
   *
   * @param yahooXMLFile - source xml for data retrieving
   * @param templateXML - template xsl for rule generation
   * @param outputXML - stores resulting xml
   */
  public void FormXML(String yahooXMLFile,
                             String templateXML, String outputXML) {
    String xmlFile = yahooXMLFile;
    String xsltFile = templateXML;

    Source xmlSource = new StreamSource(xmlFile);
    Source xsltSource = new StreamSource(xsltFile);
    Result result = new StreamResult(outputXML);

    TransformerFactory transFact = TransformerFactory.newInstance();
    Transformer trans;

    try {
      trans = transFact.newTransformer(xsltSource);
      trans.transform(xmlSource, result);
    } catch (TransformerConfigurationException e) {
      e.printStackTrace();
    } catch (TransformerException e) {
      e.printStackTrace();
    }
  }
```

Appendix 8 YahooFetcher additional data replacing in saved XML

```
  /**
   * Replaces Old value by New value in yahooXMLFile file and returns re-
sulting String
   *
   * @param yahooXMLFile - victim file
   * @param Old - old string
   * @return String consist of replaced values of yahooXMLFile file
   */
  public String ReplaceXML(String yahooXMLFile, String Old) {
    FileReader fr;

    String fileToReplace = "";
    try {
      fr = new FileReader(yahooXMLFile);

      BufferedReader br = new BufferedReader(fr);
      String s = "";
        while ((s = br.readLine()) != null) {
          fileToReplace = fileToReplace + s;
      }

        fr.close();
    } catch (FileNotFoundException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }

    return fileToReplace.replace(Old, this.getSensor());
  }
```

Appendix 9 YahooFetcher check whether sensor exists or not

```
  /**
   * Checks whether sensor exists in the database or not
   * Checking is done based on "InvalidParameterValue" parameter which oc-
curs on non-existing element
   *
   * @param checkFile - xml file with description for SOS
   * @param checkValue - value, which is replaced by sensor param
   * @return boolean true is exists, false is not
   */
  public boolean isSensorExists(String checkFile, String checkValue) {
    FileReader fr;

    String isSensorExists = "";
    try {
      fr = new FileReader(checkFile);

      BufferedReader br = new BufferedReader(fr);
      String s = "";
        while ((s = br.readLine()) != null) {
          isSensorExists = isSensorExists + s;
      }

        fr.close();
    } catch (FileNotFoundException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }

      return !PopulateXML(isSensorExists.replace(checkValue,
               this.getSensor())).contains("InvalidParameterValue");
  }
```

Appendix 10 YahooFetcher populate the XML via SOS

```
  /**
   * Populate yahooXML string into database via SOS service address and re-
turns response
   *
   * @param yahooXML - xml string for population into database
   * @return response from the SOS service
   */
  public String PopulateXML(String yahooXML) {
    String response = "";

    HttpClient httpClient = new HttpClient();
    PostMethod method = new PostMethod(this.getAddress());

    try {
      method.setRequestEntity(new StringRequestEntity(yahooXML,
                                        "text/xml", "UTF-8"));

      HostConfiguration hostConfig = new HostConfiguration();

          // apply proxy settings:
          String host = System.getProperty("http.proxyHost");
          String port = System.getProperty("http.proxyPort");
          String nonProxyHosts = System.getProperty("http.nonProxyHosts");

          // check if service url is among the non-proxy-hosts:
          boolean serviceIsNonProxyHost = false;
          if (nonProxyHosts != null && nonProxyHosts.length() > 0) {
              String[] nonProxyHostsArray = nonProxyHosts.split("\\|");
              String serviceHost = new URL(this.getAddress()).getHost();

              for (String nonProxyHost : nonProxyHostsArray) {
                  if (nonProxyHost.equals(serviceHost)) {
                      serviceIsNonProxyHost = true;
                      break;
                  }
              }
          }
          // set proxy:
          if (serviceIsNonProxyHost == false
            && host != null && host.length() > 0
            && port != null && port.length() > 0) {
              int portNumber = Integer.parseInt(port);
              hostConfig.setProxy(host, portNumber);
          }

      httpClient.setHostConfiguration(hostConfig);
      httpClient.executeMethod(method);

      response = method.getResponseBodyAsString();
    } catch (UnsupportedEncodingException e) {
      e.printStackTrace();
    } catch (HttpException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }

    // Debug feature, prints response from the SOS
    System.out.println("---START---"+response+"---END---");

    return response;
  }
```