ACCSE 2019

The Fourth International Conference on Advances in Computation, Communications and Services

ISBN: 978-1-61208-735-1

July 28 – August 2, 2019

Nice, France

ACCSE 2019 Editors

Pascal Lorenz, University of Haute-Alsace, France

ACCSE 2019

Forward

The Fourth International Conference on Advances in Computation, Communications and Services (ACCSE 2019), held between July 28, 2019 and August 02, 2019 in Nice, France, continued a series of events targeting the progress made in computation, communication and services on various areas in terms of theory, practices, novelty, and impact. Current achievements, potential drawbacks, and possible solutions are aspects intended to bring together academia and industry players.

The rapid increase in computation power and the affordable memory/storage led to advances in almost all the technology and services domains. The outcome made it possible advances in other emerging areas, like Internet of Things, Cloud Computing, Data Analytics, Smart Cities, Mobility and Cyber-Systems, to enumerate just a few of them.

We welcomed academic, research, and industrial contributions, technical papers presenting research and practical results, position papers addressing the pros and cons of specific proposals.

We take here the opportunity to warmly thank all the members of the ACCSE 2019 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to ACCSE 2019. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also thank the members of the ACCSE 2019 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that ACCSE 2019 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the field of computation, communications and services. We also hope that Nice, France provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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AirMap: A Reactive Map of Air Quality

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***Abstract*—Today, air pollution is one of the biggest environment risks to health that continues to rise and affects both people's quality of life and economies. It is identified as a global health priority by the World Health Organization, since it affects all societies around the world. A huge amount of air quality data is collected by different means, but it is not easily accessible by the citizens, who have a sensible role to mitigate the problem. In this paper, a visualization tool of multi-scaling, spatial-temporal air quality data, called AirMap, is proposed. An adaptive development method, based on modern MERN (MongoDB, Express, React, Node.js) application stack, is applied to integrate line charts with map-based localizations, trends and time views. The interactive visualization helps citizens to better understand air quality data and to compare measured air quality across places. The feasibility of AirMap is proved using a large multi-dimensional data set including measurement for 7 air pollutants and 4 weather parameters.**

Keywords*— *document database; time series data; spatial-temporal; data visualization; MERN stack.

I. INTRODUCTION

Air pollution damages the ecosystem and has a significant impact on the health of the population. The vegetation, fauna, water and soil, together with the services they support are directly affected. According to the air quality report [1] of the European Environment Agency (EEA), about 61% of the European ecosystem area remained exposed to air pollution levels exceeding limit values in urban areas and long-term exposure of particles less than 2.5 micrometers in diameter ($PM_{2.5}$) were responsible for 422 000 premature deaths in 2015. By cutting lives short, increasing medical costs and reducing productivity during working days, air pollution causes loses across the economy.

Air monitoring stations and remote sensing satellites are the main sources of air quality data. The existence of scalable and high-performance infrastructures and the rapid growth of data, leading to the so called "Big Data" phenomenon, open new opportunities for the development of data-driven applications in all domains of everyday life. The currently available air quality data sets have different levels of granularity, depending on the time basis and number of air parameters measured. They include the values of different air quality parameters, the location of monitoring stations and the time of recording. Information for the weather-related parameters, such as humanity and temperature, is also recorded. Such data sets are suitable for spatial-temporal visualization, allowing better understanding of air quality through interactive data explorations and presentation of abnormalities, trends and correlations.

The diversity of air quality data and the specifics of time series data itself, represent challenges for visualization. Usually, it is impossible to show all individual data points due to limitation of the display capabilities to a certain plot resolution on the screen and also due to the processing capabilities of the underlying hardware [2]. The transferring of data from back-end datastore to the front-end user interface burdens the performance of visualization [3][4]. In this paper, *a visualization tool of multi-scaling, spatial-temporal air quality data, called AirMap*, is proposed. AirMap allows the user to select an air quality monitoring station on the map to show line charts of 7 air pollutants (PM, O_3, NO_2, NO, SO_2, CO, C_6H_6) and 4 weather parameters (Humidity, Atmospheric Pressure, Wind and Solar Radiation). A separate chart giving insight on the tendency of a given air pollutant is provided. The air quality data can be visualized for a given period of time defined with start date and end date as well as for a fixed time slot of 1 month, 3 months, 6 months or 1 year. The usability and performance of the AirMap is validated using an air quality data set provided on the Bulgarian open data portal [17].

The *main contributions of the paper* are as follows:

- *An adaptive development method* including a multi-scale time series data visualization and interaction;
- AirMap, *a lightweight, open-source visualization tool* that enables intuitive and fast exploration of large air quality data sets.

The rest of the paper is organized as follows. Section 2 provides background information about the air quality monitoring stations, air quality and weather parameters measured on the territory of Bulgaria. Section 3 presents a comparative analysis of current spatial-temporal air visualization solutions. Section 4 describes the AirMap architecture, while Section 5 its implementation. Section 6 shows the results from AirMap testing. Finally, Section 7 concludes the paper and gives directions for future work.

II. BACKGROUND

According to the World Health Organization, in 2012 Bulgaria had the second highest air pollution related mortality in Europe [5]. Air pollution causes cardiovascular, respiratory, endocrine and oncology diseases. The air of Sofia depends on climate and micro-climate conditions, the quantity and type of emissions and the location of emissions' sources. The closed nature of Sofia valley is a prerequisite for the retention of air masses, frequent occurrence of temperature inversions and fog occurrence. The natural dispersion of emissions is poor, leading to their remaining in the air. That is why the use case scenario to validate the proposed platform is based on the air quality data of Sofia Municipality.

 ISBN: 978-1-61208-735-1

The Executive Environment Agency (ExEA) of Bulgaria regulates eight monitoring stations of air quality on the territory of Sofia Municipality – Orlov most, Gara Yana, Druzhba, Nadezhda, Hipodruma (Krasno selo), Pavlovo, Kopitoto and Mladost (see Table I).

TABLE I. AIR QUALITY MONITORING STATIONS

Station	Station code				
	Latitude	*Longitude*	*EoI station code*	*Station Area*	*Station Type*
Orlov most	42.690353	23.33605	BG0054A	U	T
Gara Yana	42.727489	23.556006	BG0024A	S	B
Druzhba	42.666508	23.400164	BG 0052A	U	B
Hipodruma	42.680558	23.296786	BG0050A	U	B
Pavlovo	42.669797	23.268403	BG0073A	U	T
Kopitoto	42.637192	23.243864	BG0070A	R-N-C	B
Mladost	42.655488	23.383271	BG0079A	U	T
Nadezhda	42.732292	23.310972	BG0040A	U	B

Table II shows the air parameters, whose values are collected through the air quality measurement stations.

TABLE II. AIR QUALITY DATASET PARAMETERS

Parameter	Metric
PM (Particulate Matter)	***µg/m3***
Sources: The main sources of PMs are industry, transport, energy and domestic heating. During the local heating season, the main source of PMs is the burning of solid and liquid fuels in the household. This is due to low chimneys and specific weather conditions during the winter season, which reduces the possibility of dispersing atmospheric pollutants.	
NO_2 (Nitrogen dioxide)	***µg/m3***
Sources: High-temperature combustion processes (Energy, Internal combustion engines).	
NO (Nitrogen oxide)	***µg/m3***
Sources: High-temperature combustion processes (Energy, Internal combustion engines).	
C_6H_6 (Benzene)	***µg/m3***
Sources: Benzene is mainly used as a raw material in the chemical industry. It is thrown away by emissions from motor vehicles and evaporation when working with oil (petrol stations and refineries).	
CO (Carbon oxide)	***µg/m3***
Sources: The largest source is the road transport – over 65% of the total emitted quantity, heat plants, industry and others.	
O_3 (Ozone)	***µg/m3***
Sources: Ozone is not emitted directly into the atmosphere. It is formed by the interaction of nitrogen oxides and volatile organic compounds under the influence of high temperatures and sunlight.	
SO_2 (Sulfur dioxide)	***µg/m3***
Sources: Industry, energy, coal-fired heating with a lot of sulfur.	
Humidity	***%***
Atmospheric Pressure	***mbar***
Wind	***m/s***
Solar radiation	***W/m2***

The EEA classifies the air quality stations according to the following criteria:

- Type of station – traffic (T), industrial (I), background (B);
- Type of zone – urban (U), suburban (S), rural (R), rural near city (R-N-C), rural regional (R-R), rural remote (R-R);
- Measurement regime (continuous, periodic).

The measurement regime of all stations is continuous data collection. They are part of the national air network.

III. RELATED WORK

This section presents a comparative analysis of the currently available applications for visualization of air quality data. The comparison is based on the most important characteristics, as follows:

- Usage of Open Data (OD);
- Geo-Location (GL) of air quality monitoring stations;
- Number of Pollutants (NP) that are visualized;
- Visualization if Referent Values (RV) of air parameters;
- Visualization of Weather Parameters (WP) such as Temperature (T), Humidity (H), Wind (W), Pressure (P);
- Multi-Scaling (MS), meaning that the time series data can be displayed at different levels of detail depending on the selected time slot and air quality parameters;
- Forecasting (F).

Table III presents the results from the comparative analysis. The last row of the table shows the proposed solution.

TABLE III. RESULTS FROM COMPARATIVE ANALYSIS

Solution	OD	GL	NP	RV	WP	MS	F
Luftdaten.info	yes	yes	PM10, PM2.5	yes	no	no	no
AirVisual Earth	no	yes	PM10, PM2.5	yes	W	no	no
AirVisualMap	no	yes	PM2.5, AQI	yes	T, H, W, P	no	yes
World AQI project	yes	yes	PM2.5, O3, NO2, CO, AQI	yes	T, H, W, P	no	yes
BreezoMeter	no	yes	PM10, PM2.5, O3, NO2, CO, SO2, AQI	yes	no	partial	yes
European Air Quality Index	yes	yes	PM10, PM2.5, O3, NO2, SO2, AQI	yes	no	partial	no
Air Quality in Scotland	yes	yes	PM10, PM2.5, O, NO2, CO, SO2, AQI	yes	T, W	yes	yes
Berkeley Earth	yes	yes	PM2.5, AQI	yes	no	yes	no
Plume Labs AIR map	yes	yes	PM2.5, PM10, NO2, O3	no	no	yes	no
Hungarian Air Quality Network	no	yes	PM10, NO2, NOx, NO, SO2	yes	no	yes	no
Nowcast	no	yes	PM10, PM2.5, O3, NO2	yes	no	no	no
Air Quality in Cyprus	no	yes	PM10, PM2.5, O3, NO2, NO, NOx, SO2, C6H6	yes	no	yes	no
AirMap	yes	yes	PM, O3, NO2, NO, NOx, SO2, C6H6	yes	T, H, W, P	yes	no

OK Lab Stuttgart is dedicated to the measurement of PMs within the Citizen Science project luftdaten.info. Citizens around the world install self-built sensors outside

their home. Luftdaten.info visualizes the transmitted data on a continuously updated map [6]. AirVisual Earth covers pollution airflows across the world by combining PMs data from public government air quality monitoring stations, satellite data and community [7]. The visualization on the map shows that the larger cities are both a cause and a victim of air pollution, depending on the wind direction and speed. AirVisual Map shows an interactive heatmap of PMs and Air Quality Index (AQI) together with the wind direction [8]. The user is able to select an air quality monitoring station, to view details about the values of pollutant, the AQI and the environment parameters as well as an air quality and weather hourly forecast. The World Air Quality Index project is a non-profit project showing in real-time the air quality data for more than 60 countries [9]. The air quality map of BreezoMeter helps citizens to understand the concentration levels and health effects of six air pollutants and to make informed decisions [10]. The user is provided with actionable health recommendations regarding indoor and outdoor staying, health sensitivities, sport activities and the risk for children. Additionally, the concentration level of pollen in the air and 24-hours history data of AQI are given. European Air Quality Index is an online service of the EEA and the European Commission. An interactive map can be zoomed in or searched for any city or region in Europe to check the overall air quality and concentration levels of key pollutants. An overall rating for each air quality monitoring station is marked by a colored dot on the map, corresponding to the worst rating for any of the five pollutants. The air quality situation at each of more than 2000 monitoring stations is presented in a short-term. Ricardo Energy & Environment provides mapped concentrations of pollutants for Scotland [11]. The data visualization supports multi-scaling based on a selected time period and air parameter. Time series data can be zoomed into the graph by clicking and dragging inside the graph area. All graphs can be exported in various formats. Berkeley Earth is an effort started in April 2014 to collect and analyze the world's air pollution data [12]. A near real-time data of PMs is presented on a map. Health indicators and qualitative descriptions are included based on the US EPA's air quality index standard for 24-hour exposure. Plume Labs developed a world air map of air pollutants, which also provides health recommendations for citizens' activities [13]. The map visualizes an open data from public land-based monitoring stations, which is blended with satellite imagery for better accuracy. Current and historical air quality monitoring data is provided by the Hungarian Air Quality Monitoring Network at national level [14]. The network consists of two mayor parts: automatic monitoring stations with continuous measure of wide range of air pollutants in ambient air, and manual system with sampling points and consecutive laboratory analysis. The data is visualized on a map and graphs for individual air pollutants are available. The visualization of historical data is limited to a period of 366 days. Nowcast map shows the current air pollution in detail across London in comparison with the UK Government's Daily Air Quality Index [15]. The user is able to click on the map, drag a marker, or enter a postcode to see the pollutant concentrations at the selected location. Since measurements from monitoring stations are only able to report air quality at that particular place, Nowcast combines these measurements with a detailed model to show a prediction of what air quality is like across the whole area of London. Health advice of current location is also provided. The map visualization of air quality in Cyprus shows the current concentrations of pollutants for each monitoring station [16]. Additionally, a graph visualization of a variety air pollutants is available for different periods of time. The pollutant concentration values displayed at each station are in real-time, and as such, are not validated.

Table III shows that only 2 solutions – AirVisualMap and World AQI project, provide visualization of all weather's parameters, namely temperature, humidity, wind and pressure. At the same time, the visualization of pollutants is limited to 1 for the AirVisualMap and 4 for the World AQI project. In addition, they do not support multi-scaling at different levels of detail. Therefore, none of the presented solutions provide a complete visualization of both air pollutants and weather's parameters with option for multi-scaling on selection of time slot and air quality parameters.

IV. AIRMAP ARCHITECTURE FRAMEWORK

The architecture framework of *AirMap* consists of three main layers, shown in Figure 1:

- Data Layer – provides data persistent mechanisms, which are responsible for storing and retrieving data that is requested by the server layer;
- Server Layer – handles requests coming from the client layer by applying processing rules and sending responses with requested content;
- Client Layer – provides user's interaction interface available for access via web and mobile browsers.

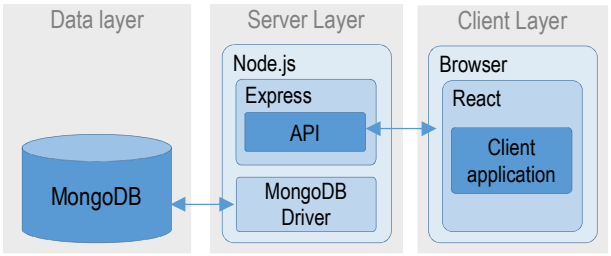

Figure 1. Architecture framework of AirMap

The architecture framework of *AirMap* follows a modern application stack, including MongoDB, Express, React, Node.js (*MERN* stack). *MongoDB* is an open-source document database that ensures persistence of data. It bridges the gap between the relational databases having a rich functionality and the key-value stores providing scalability and high performance. The JSON-like documents in *MongoDB* database allow the data structure to be changed over the time. The access and analysis of data are supported by ad-hoc queries, an indexing and a real time aggregation.

Node.js is a JavaScript runtime environment, which contains a built-in HTTP server library and thus allows for implementation of web servers. This provides a greater control over how the web server works. In the traditional web server's implementations, each request initiates a new thread, taking up system RAM and eventually maxing-out at the amount of RAM available. In contrast, *Node.js* operates on a single-thread, using non-blocking I/O invocations. Thus, it supports tens of thousands of concurrent connections held in the event loop. On completion of the requested task, the requestor is informed of the results via a callback. As a result, scalable network applications could be developed, capable to handling a huge number of simultaneous

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connections with a high throughput. Historical images including maps of sources and concentrations of five pollutants, as well as trends over time are also supported.

Express is a Web application framework, which runs as a module within the *Node.js* environment. In the context of the current solution, it provides a REST API giving to the client layer access to *MongoDB* database using HTTP network calls.

React (referred also as ReactJS) is a JavaScript library for building reactive, interactive user interfaces. It breaks the front-end applications down into components. The components hold their own state. The state can be passed down from parent components to child components. The latter can pass changes back to the parent components using callbacks.

V. AIRMAP IMPLEMENTATION

This section describes the implementation of *AirMap* following the proposed architecture in Section IV.

A. Data Layer

The Air Quality data set is provided on the open data portal of Bulgaria [22]. It contains a continuous record of the air parameters displayed on the Sofia Municipality's website [18]. Data is not official, since it does not come directly from the ExEA – an administration within the Ministry of Environment and Water. It is obtained through a constant analysis of the graphics posted on the Sofia Municipality's website. It is therefore possible to deviate by up to 0.5% of the actual values.

The data set contains measurements from six air quality monitoring stations – Druzhba, Nadezhda, Pavlovo (Krasno selo), Kopitoto, Mladost for all air parameters in Table II. The data acquisition has started at 16:00 on 20 January 2016. Each row shows the date and time, the station code, the pollutant code, its level, and whether it is marked as invalid. If the last metric is '1', then the EEA has noted that there is any dirt on the meter or any other reason that has led to an erroneous value. The Air Quality data set provides a time series data, which is imported in the *MongoDB* database as a single collection, called *airdata*. There are three main configurations that can be applied to the design of time series schema in *MongoDB*: (1) one document per data point; (2) bucketing the data using one document per time series time range; and (3) one document per fixed size [19]. The first configuration is used for the current implementation. Thus, each record in the data set corresponds to a separate JSON-like document in the *airdata* collection. This is the most comfortable modeling concept, because the data comes from a tabular schema (CSV format). The working with data is easy, since the document model maps to the objects directly in the application code.

The design of schema produces the largest number of documents and collection size per unit of time, but it is acceptable for the current application, since the size of data imported to the database is fixed, i.e., the data is not continuously ingested in the database.

B. Server Layer

A server application (server.js) is developed using *Express* and *Node.js*. When *Node.js* server initializes the event loop, it starts. Then, it processes the provided input script, which makes asynchronous API calls and proceeds with the event loop. The event loop consists of several phases, which are executed in a given order as follows:

- timers – executes callbacks that are scheduled by timers;
- pending callbacks – executes I/O callbacks deferred to the next loop iteration;
- idle, prepare – for internal use only;
- poll – calculates how long it should block and poll for I/O, then processes events in the poll queue;
- check – executes callbacks immediately after the poll phase has completed. If the poll phase is idle, the event loop is able to proceed with the check phase rather than waiting;
- close callbacks – performs close on callbacks.

The *Node.js* server processes HTTP GET requests to retrieve data into the callback without blocking the main stack. The working process of *Node.js* is shown in Figure 2. In order to prevent server overload, the number of retrieved records is limited. The limit can be changed depending on the available hardware resources.

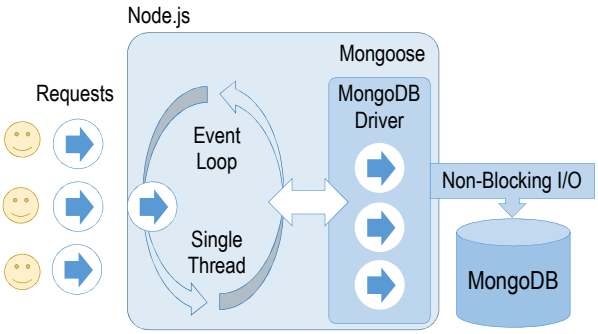

Figure 2. Node.js working process

C. Client Layer

The client application is built on *React* library and its wrapper *Highcharts*. It consists of small reusable components, which allow the User Interface (UI) to be divided into small pieces and to be built in a comprehensive way. The programing concept behind the *React* components is the virtual Document Object Model (DOM), meaning that the "virtual" representation of UI is kept in memory and synced with the "real" DOM. The virtual DOM is a lightweight copy of the real DOM, providing fast updating using a diffing algorithm. Two virtual DOMs are maintained at any given time by *React* – one that is related to the updated state of the data model and another one that is related to its previous state. The diffing algorithm compares both virtual DOMs to find the changes and to update the real DOM, as is shown in Figure 3. Its complexity is O(n), since it adopts a heuristic approach with some assumptions to find the minimum number of modifications between two trees. The main benefit of this approach is that the changes don't need to be tracked and the expensive DOM operations are minimized. Thus, when the whole UI is re-rendered, the final result will include only the changes [20].

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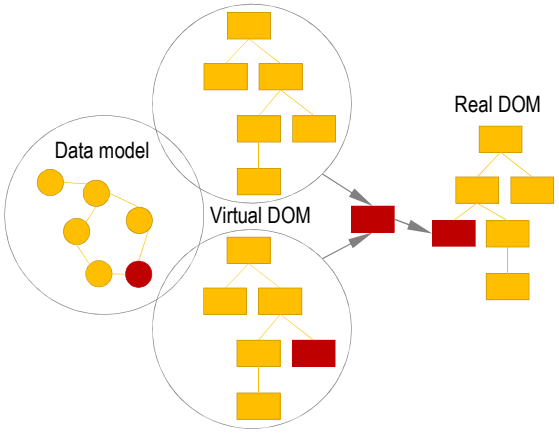

Figure 3. Virtual DOM and diffing algorithm, adapted from [20]

Three *React* components are implemented as follows:

- *Map* component – visualizes the air quality monitoring stations on a map;
- *Chart-Compare-Parameters* component – visualizes the air parameters;
- *ViewPort* component – contains the *Map* component and the *Chart-Compare-Parameters* component.

Figure 4 shows an UML diagram of the components.

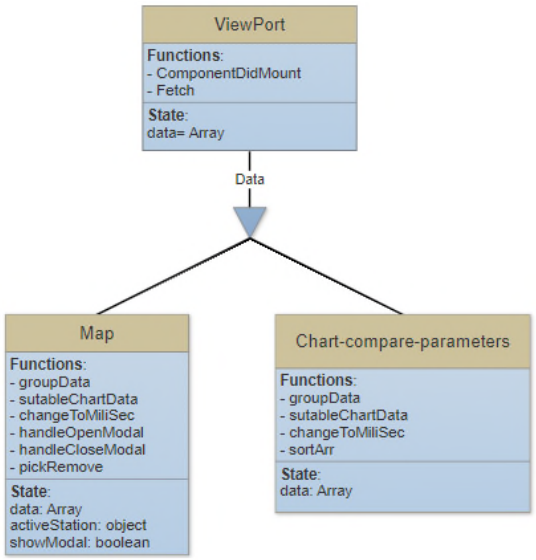

Figure 4. UML component diagram

The *Map* component and the *Chart-Compare-Parameters* component are nested in the *ViewPort* component. Thus, a more complex user interface structure is created, while keeping the simplicity of the application. The *Map* component uses google-maps-react module, which allows for integration of Google Maps service. The stations are localized based on data for latitude and longitude that is obtained from *MongoDB* database.

The *Chart-Compare-Parameters* component makes HTTP GET requests to the *Node.js* server application. Its lifecycle is shown in Figure 5, but it is applicable to all *React* components.

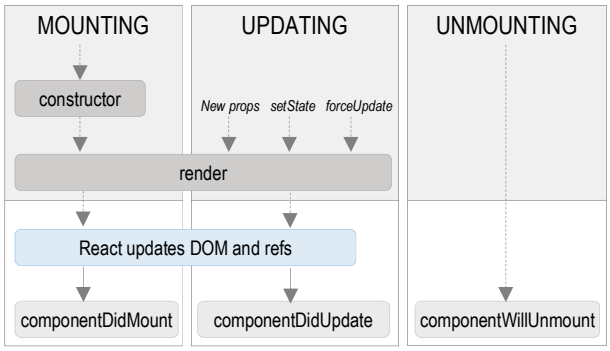

Figure 5. Lifecycle of React component

When an instance of the *Chart-Compare-Parameters component* is created and inserted into the DOM, the following methods are called: *constructor()*, *render()* and *componentDidMount()*. The *constructor()* method is called before the component is mounted. The *render()* method returns *React* elements that instruct *React* to render a DOM node. It does not modify the state of the component, meaning that it returns the same result each time it is invoked. Since *render()* method does not directly interact with the browser, the *componentDidMount()* method is called. It is invoked immediately after the component is inserted in the DOM tree. The *componentDidMount()* method instantiates the network request to the *Node.js* server in order to retrieve the air quality data. The *componentDidUpdate()* method is invoked immediately after updating occurs. Finally, the *componentWillUnmount()* method is invoked immediately before the component is unmounted and destroyed.

Time series data for each air quality monitoring station is separated into different *Highcharts* objects. Additional *Highcharts* objects are created for visualization of referent values of air parameters as well as for smooth representation of their tendency. The smooth representation separates long-trends and seasonal changes from the random fluctuations and gives a better picture of time series data. Here, two types of methods can be applied: (1) global methods that include fitting a regression over the whole time series; and (2) local methods, where a constraint is applied by a single parametric function. Since the global methods assume that the time series follow a single trend, which is not applicable to the air parameters, a local method is applied in the current implementation. Thus, the variation at the beginning of the time series does not affect measurements near their end. The moving average method (referred also as running mean) has been selected for implementation of the local smoother. It assigns an equal weight of each value in the data set and calculates arithmetic mean of a given set of values defined by a smoothing parameter. Let's define x_i as a value at the time i. Let $X = x_1, x_2, \ldots x_p$, where p is the length of the time series. The moving average method at the time t is calculated as follows:

$$MA_t^n = \frac{1}{n}\sum_{i=1}^{n} x_{t-1}, \qquad (1)$$

where n is a smoothing parameter that determines the averaging window width [21].

The *pickRemove()* function takes as parameter an array of values to be processed and returns a new array with average values. First, it checks whether the input parameter is passed. Next, another function, called *groupAverage()*, is invoked,

which is responsible for actual implementation of the moving average method. The value of the smoothing parameter is 45.

VI. AIRMAP VALIDATION RESULTS

AirMap is tested using different browsers (Internet Explorer, Google Chrome, Opera and Mozilla FireFox) under Window 10 operation system. The hardware configuration includes processor Intel Core i3 and 8GB RAM.

The visualization of the air quality monitoring stations on the map is presented in Figure 6. A sample chart with the values of NO_2 for all quality monitoring stations is also shown. Additional information about the station such as type (background or traffic), station area (urban or rural) and EoI station code (as in AirBase of EEA) is visualized in a popup window when the user clicks on the station's location.

The following visualization options are provided:

- show data from one or more air quality monitoring stations;
- show data for a given period of time defined with start date and end date;
- show data for 1 month, 3 months, 6 months or 1 year;
- show or hide a separate chart giving an insight about the tendency of a given air parameter.

Table IV shows the results of performance testing of *AirMap*. 12 test cases are designed that cover visualization of different amounts of data depending on the selected options by the user. Additional 4 test cases are performed to analyze the behavior of the application under high data load. In the worst case, all data from *MongoDB* database is visualized (1,048,576 documents).

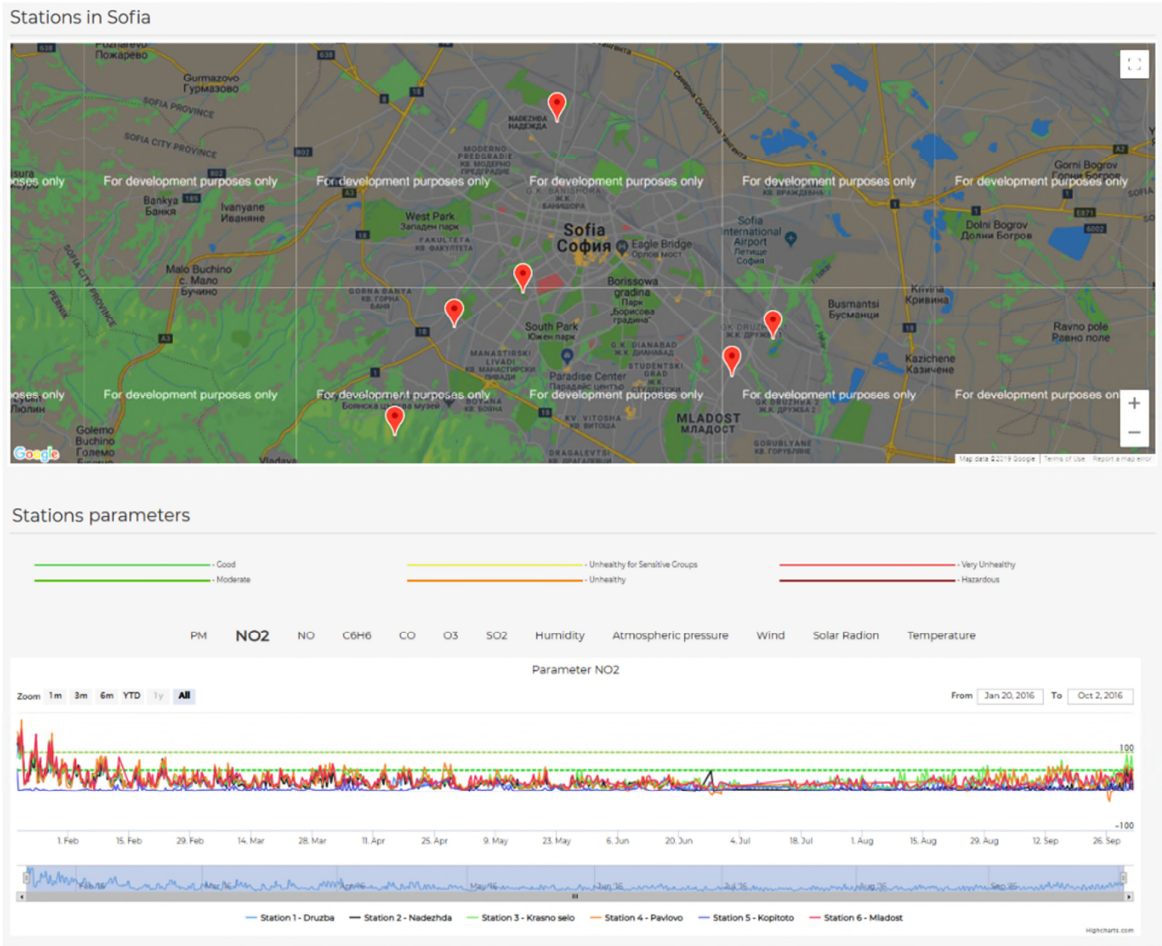

Figure 6. Values of NO_2 for all air monitoring stations

TABLE IV. AIRMAP PERFORMANCE TESTING

Chart Data	Loading time [s]			
	1m	*3m*	*6m*	*2 Years*
1 air parameter for 1 station	0.2	0.3	0.5	1.5
1 air parameter with a trend	0.2	0.3	0.5	1.5
1 air parameter for all stations	0.5	1	1.5	5
All air parameters for all stations	3	6	9	15

The results in Table IV prove that the visualization is performed in an efficient way. The content loading is fast due to the virtual rendering technique applied. If the number of retrieved records exceeds 900 000 (rendering of all data in the air quality data set), the response time of the application becomes high. This is expected given the hardware resources of the testing machine, as well as the data volume. That is why, the maximum data that the user is able to load is limited to all values of one parameter (2-year period) for all monitoring stations.

 ISBN: 978-1-61208-735-1

Usability testing has been used to evaluate user interaction with *AirMap*. It is done by real-life users – students, who have been attended the Software testing course of Software Technologies master program in the Faculty of Mathematics and Informatics at Sofia University. A total of 15 students have been participated in the testing process. They were asked to externalize thoughts and feelings when interacting with *AirMap*. Quantitative information such as time on tasks, success and failure rates, effort (number of clicks, perception of progress) was collected. In addition, qualitative information about stress responses, subjective satisfaction, perceived effort or difficulty was gathered. Non-critical errors that are recovered by the students and do not result in the students' ability to successfully complete the task were detected and fixed later. The outcomes from the testing session prove that *AirMap* provides a sufficient level of usability.

VII. CONCLUSIONS

This paper proposes a tool for multi-scaling, spatial-temporal visualization of air quality data, called *AirMap*. *AirMap* allows the user to select an air quality monitoring station on the map, to show line charts of a variety of air parameters and their trends for different slots of time. The usability and performance of the *AirMap* is validated using an air quality data set provided on the open data portal of Bulgaria. The results from testing show that *AirMap* provides a sufficient user experience due to the fast loading of data and the efficiency of user's interaction.

The future work includes development of functionality for automated import of air quality data to the *MongoDB* database. Additional direction will be implementation of an option for visualization of all air parameters for a single monitoring station.

ACKNOWLEDGMENT

This work was supported by the Bulgarian National Scientific Fund within the project no. DN 12/9 and by the European Commission under grant agreement no. 857155.

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 ISBN: 978-1-61208-735-1

Application of Bioinspired Algorithms for the Optimization of a Radio Propagation System Simulator Based on OpenStreetMap

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***Abstract*—This work aims to solve the need for an advanced radio propagation prediction tool in outdoor environments. A previous simulator developed by the authors is improved by adding new algorithms that extend the application to a new, more advanced and complete version. This extension is developed in JavaScript, HTML5 and Cascading Style Sheets, using Bootstrap as a framework to achieve an intuitive and friendly application that adapts to all screens. The tool is easily accessible through the Web and includes an intuitive graphical interface to introduce the simulation parameters and to show the obtained results.**

Keywords- OpenStreetMap; propagation losses; optimization algorithms; evolutionary algorithms; simulation.

I. INTRODUCTION

This work is conceived as a continuation of the paper published in [1], whose objective was to develop a simulator able to obtain the radio propagation losses in external environments quickly and accurately. The main advantage of this tool was that the information of the environment was obtained from OpenStreetMap [2], which provides very detailed geographic data from any part of the world required to calculate the propagation losses. This paper aims to improve that computer tool incorporating different evolutionary algorithms to optimize the position of the antennas so that the coverage provided is the best possible, while minimizing the number of antennas. Since each optimization algorithm has its advantages and disadvantages, several algorithms will be implemented and the tool will carry out the same simulation by applying each of them and will show the output of the one that offers the best results, that is, the one that better suits the particular conditions of each environment. Six empirical methods for computing the radio propagation losses in outdoor environments will be available (Okumura-Hata [3][4], COST 231 [5], Longley-Rice [6], Walfish-Bertoni [7], Walfish-Ikegami [8], and Eibert and Kuhlman [9]). Since the optimizations can take a long time, the code will be parallelized taking advantage of the processors that include several cores. With this parallelization, we will try to minimize the calculation time required by the evolutionary algorithms. The tool developed will be validated with real measurements. Several antennas will be placed in the optimized locations in order to obtain the best coverage in a certain area (the surroundings of the University of Alcalá (Alcalá de Henares, Spain)). The tool will be available both for wireless devices (smartphones, tablets, portable PCs, etc.) and for desktop computers. It will be multiplatform, since it will be developed using Javascript, Cascading Style Sheets (CSS3) and HTML5. Figure 1 shows the graphical user interface of the previous tool (before the improvements) and the tool that is currently being improved. The rest of the paper is structured as follows. In Section 2, we present the related work. In Section 3, we present the new features of the tool. Finally, we conclude in Section 4.

II. RELATED WORK

Nowadays, smartphones have become indisputable accessories and indispensable for all. We depend on them to check the weather, to plan the holidays, access bank details, check the mail, etc. That is why having a good radio propagation coverage that fulfills all our demands at all times is highly desirable. As a result of this, the study of propagation losses has become a vital task when developing any mobile communication system. As an alternative to the expensive and tedious measure campaigns that must be carried out to study radio propagation in a specific area, software tools that carry out this task are generally used. In recent years, several tools have been developed [10]-[14] based on both deterministic and empirical methods. These tools require some knowledge of the environment to extract the information needed by the propagation model implemented, which can be obtained from various sources such as government institutions, satellite images, city planning maps, etc. In this case, OpenStreetMap allows to obtain geographic information easily from the Internet. Another of its many advantages is that OpenStreetMap provides an application programming interface that allows to develop applications using the information contained in the maps.

On the other hand, it is also important to mention that many optimization problems that arise in the field of engineering are very complex to solve using traditional algorithms, so evolutionary algorithms are generally implemented, which are inspired from nature and are based on the natural evolution of living beings. The application of this type of algorithms in complex optimization problems

 ISBN: 978-1-61208-735-1

originates in 1960, when Holland [15] solved an artificial intelligence problem through evolutionary strategies based on the natural evolution of the species. Since in those times its practical application was impossible, it was only described theoretically, explaining the adaptive process of natural systems and how to design artificial systems that emulate the essential mechanisms of natural systems.

Evolutionary algorithms have been very successful since the 60s to the present day because they have proven to be useful in search and optimization problems in many fields such as engineering, science, administration and industry. In addition, they are simple, easy to understand and design, have no limitations on the objective function, are robust and reasonably efficient. For this reason, from the work of Holland, other research channels appeared, such as Genetic Algorithms [16], Genetic Programming [17], or Evolutionary Programming [18]. The basic characteristics of all of them are the following:

- They use codings of the solutions that are generally associated with strings of symbols or bits (binary coding).
- The parameters to be optimized are modified from a set of previously established search space points.
- In each iteration or generation, they only use the value of the objective function (instead of using derivatives or other more complex calculations).
- They use probabilistic transition rules instead of using deterministic rules.

In addition, all of them adapt to changes in the environment to find an optimal solution to a problem, developing a population of candidate solutions during a generation based on the aptitude values of each candidate and applying crossover, mutation and selection techniques. Each type of evolutionary algorithm has its own specificities, which makes them different from each other. The fundamental characteristic common to all of them is that, being inspired by Darwin's theory of evolution, the fittest individuals will have a higher probability of reproduction. In turn, the individuals descended from these individuals will have a greater possibility of transmitting their genetic codes to the next generations. In this way, it will be possible to obtain a final generation that will be the optimal generation, that is, the optimal solution of the problem to be solved.

Moreover, the tool will also include other bio-inspired algorithms based on swarm intelligence, such as bees [19], ant colonies [20] and flocks of birds [21]. These three algorithms focus on the fact that the environment changes continuously and organisms must be able to adapt to these changes and act accordingly. These techniques allow to implement flexible and robust systems at the same time.

III. NEW FEATURES

Starting from the work done in the previous simulation tool, and considering the previous contributions to the scope of this work, the innovative effect of the proposed tool and its novelest aspects could be broken down into the following points:

- The tool will include several optimization algorithms that will provide the optimal location of the antennas in order to obtain the maximum level of signal in each simulation. In particular, genetic algorithms, evolution strategies, evolutionary programming and genetic programming will be available.
- The user will be able to specify a particular algorithm or can execute the full simulation option in which all of them will be executed and the best results will be displayed.
- The code of the optimization algorithms will be parallelized in order to minimize the calculation time and thus speed up the simulations.
- The position of any number of antennas can be optimized, which must be established as an input parameter.
- The possibility of carrying out a multi-objective optimization will be offered in which, in addition to optimizing the position of the antennas, it will also be possible to optimize their radiation power. The default option will be to display antennas that have the same characteristics to simplify the calculations, but the user will have some advanced options in which he/she can configure, in addition, the optimization of other parameters.
- Several propagation models (Okumura-Hata, COST 231, Longley-Rice, Walfish-Bertoni, Walfish-Ikegami, and Eibert and Kuhlman) will be included to analyze which is the model that provides the best results for a certain environment.

IV. CONCLUSION AND FUTURE WORK

Most of the new features mentioned in the previous section have been already implemented. Therefore, it is expected that the final version of the tool will be available soon. Future work includes testing and validation. A measurement campaign will be carried out and the obtained results will be compared to the simulations provided by the tool.

ACKNOWLEDGMENT

This work is supported by the Vice rectorate for Research and Knowledge Transfer of the University of Alcala (Spain) through project CCG2018/EXP-020.

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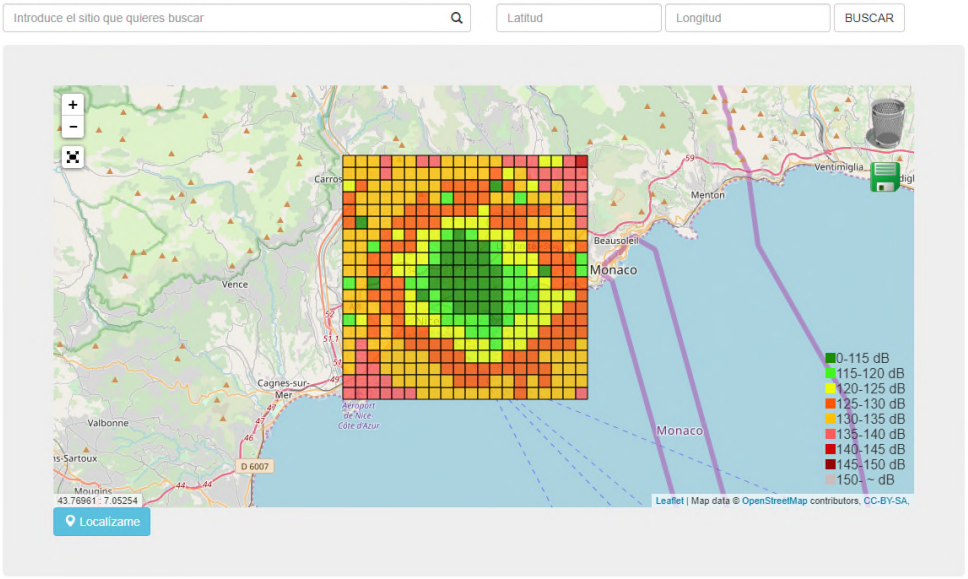
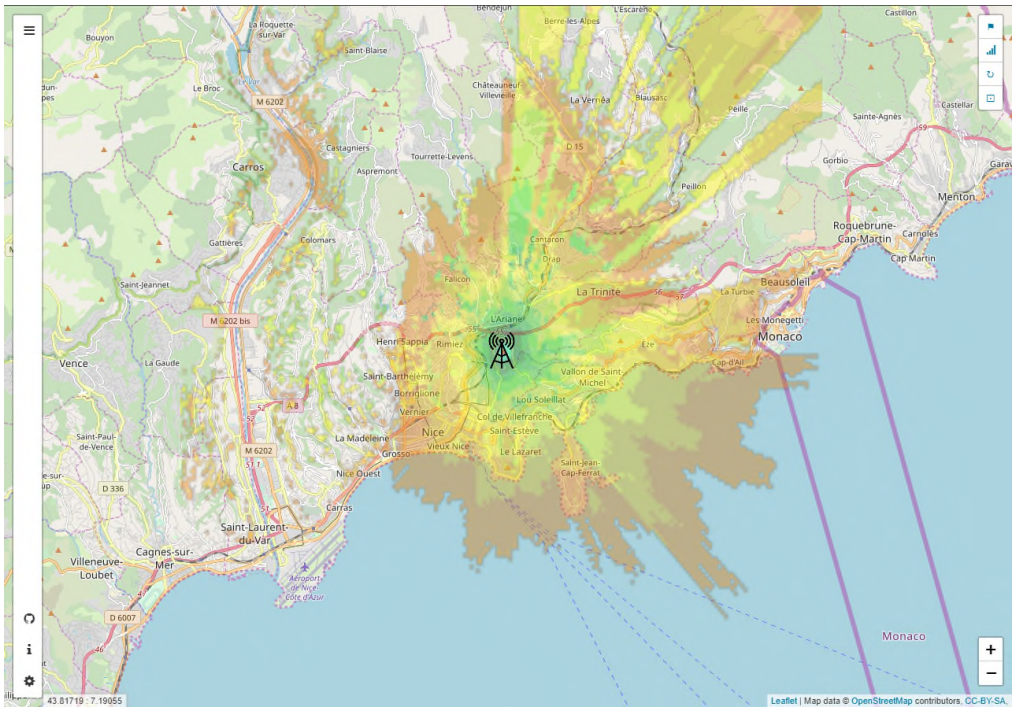


(a)



(b)

Figure 1. Graphical user interface of both simulation tools: (a) before the improvements, (b) after the improvements (work in progress).

Development of Competence Maps for Training Programs Based on the European Frameworks e-CF and ESCO

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***Abstract*—This work aims to develop a system capable of aligning different Information and Communication Technology (ICT) training programs (degrees, masters, courses, etc.) with the main European competence frameworks that are beginning to be implemented in Europe and the rest of the world. This alignment will be carried out through competence maps, which directly relate the contents taught in each training program with the competences included in the European standards.**

Keywords- training; competence; European; framework.

I. INTRODUCTION

It is a fact that today's education systems must be modernized to ensure that young people have the right skills and are prepared for the jobs of the digital economy. Employers need access to more accurate and up-to-date information on skills and qualifications to better manage their workforce, and employment services should incorporate digital technologies to more efficiently assign job-seekers with job vacancies and improve their job opportunities. This is particularly important in a context of digital skills gaps, which are both a barrier to people's employment opportunities and a risk to economic growth. Despite the high levels of unemployment in Europe, especially among young people, 40% of employers do not find people with the right skills to fill their vacancies [1]. Guaranteeing a fair labor market and allowing citizens to adapt to the changes of an increasingly digital world are key priorities of the European Commission (EC), as established in the European Pillar of Social Rights [2].

European frameworks based on competences have been conceived as a tool to help mutual understanding and to provide a common language to articulate the competences required and acquired by ICT professionals. Through this semantic interoperability, an attempt is made to alleviate the communication gap that exists between different countries and between different sectors of employment, education and training. Transparency in these areas is also enhanced by agreeing on the definition of work profiles, qualifications, skills or abilities, and learning outcomes.

The e-Competence Framework (e-CF) [3], described in European standard EN16234-1:2016, and the European Skills, Competences, Qualifications and Occupations (ESCO) [4] have been primarily discussed and from their study and the analysis of their possible convergences, the competences maps of each training program have been developed. It is important to point out that the European job classification ESCO, which was published in 2017, will be a mandatory reference for public employment services of the member states of the European Union (EU) in 2020, establishing a multi-language reference terminology reflecting the realities of both the labor market as well as the education and training sector.

In parallel, and given the need to adapt curricula, job offers, candidate profiles, etc., to the European competence frameworks, a training course on these standards has also been developed by the authors to make these frameworks known in the field of education as well as in the labor market. The training program shows the practical aspects of e-CF and ESCO through concrete examples in which its use can be seen in real cases. The audience to which this course is addressed would be formed by:

- ICT professionals who wish to assess and visualize their skills / abilities, identify their possible learning paths, or improve their ICT knowledge and correct their deficiencies.
- Managers and human resources departments involved in the administration of human resources.
- Organizations that provide ICT services, ICT users and ICT providers.
- Educational institutions and training organizations, including higher education, interested in promoting courses that are linked to digital skills and ICT work profiles.
- Certification providers, interested in certifying the digital skills of ICT professionals.
- Social agents, professional entities and accreditation bodies.
- Market analysts and regulators.
- Other organizations and stakeholders from the public and private sectors.

The paper is organized as follows. Section II describes the related work. Section III lists the benefits of the maps and finally, the concluding remarks are included in Section IV.

 ISBN: 978-1-61208-735-1

II. RELATED WORK

The authors have previously worked with the e-CF and ESCO standards in the European projects e-Skills Match [5]-[7] and e-CF Council [8]. The first was co-financed by the European Commission (EC) (The Directorate-General for Communications Networks, Content and Technology (DG CONNECT)) under the pilot program "Open Knowledge Technologies: Mapping and Validating Knowledge" related to the H2020 program [9]. The project began in September 2015, lasted 24 months and had a total budget of 1,112,787 euros. Among the project participants were partners from four European countries: Sweden, Italy, Spain and Greece. The objective of the project was to create a system for learning digital professional and user skills with dynamic adaptation to changes in job classification systems as part of the European Area of Skills and Qualifications (EASQ). The platform developed in the e-Skills Match project allows the self-assessment of competencies for specific positions, the connection with training modules that allow acquiring the skills of a given position and a qualification system for each competence. The system takes as reference the European models e-CF, ESCO and the European digital competence framework also known as DIGCOMP [10]. Regarding the e-CF Council project, included in the Erasmus + Skills Alliance program [11], it started in 2015 and had a funding of 871,000 euros. The members of the consortium, which was financed by the EC until 2018, were organizations that represent the reference groups in ICT professionalism in four member states of the EU: Italy, Spain, Bulgaria and the Netherlands. In addition, the e-CF Council had central associations recognized by the EU, such as Digital Europe, European Digital Small and Medium-sized Enterprises Alliance, e-Skills Association, etc. This project aimed to create an alliance of management of qualifications and certifications based on the e-CF standard to promote the professionalism of ICT at a European and international level. Its objective was to increase employability in order to reduce the gap of ICT competences in Europe by developing unified programs and certifications of professional training in ICT. On the other hand, since January 2018 the authors have been working on the European project "Support services for the development of version 4.0 of the e-Competence Framework", which lasts two years. The objective of this project is the development of the new version of the e-CF standard to update it and adapt it to the new changes introduced in the ICT sector.

In addition, European authorities continue to promote projects similar to those mentioned above due to the high unemployment rates among young people and the growing employability in the ICT sector in Europe. One of these initiatives has been "Grand Coalition for Digital Jobs" [12], which was launched on March 4, 2013 in Brussels. The theme of the conference was "e-Skills and Education for Digital Jobs" and its main objective was to facilitate the adoption of measures to improve digital capabilities in the EU countries. The objectives of the EU for the period 2014-2020 are the promotion of the professionalization of ICT and the generation of a greater group of talents of entrepreneurs, business leaders, managers and advanced users focused on the strategic use of new technologies of the information and communication. The EC is aware of the need to develop initiatives to ensure sufficient supply of adequately qualified ICT professionals and the need to encourage the younger population to pursue careers related to ICT. This fact is not unique to Europe, since the shortage of ICT vocations has also been identified in the United States and other developed countries. A report funded by the EC [13] estimates that up to 756,000 job vacancies by 2020 will not be filled due to the lack of qualified ICT professionals. This estimation, together with previous analyzes, has led the EU to launch specific initiatives related to eSkills and digital competences ("eSkills for Jobs", "Digital Agenda for Europe", "ICT Certification in Europe", "e-Leadership Digital Skills" for SMEs ", etc.) to help more people get jobs related to ICT throughout Europe.

On the other hand, the current analysis has shown that the level of interoperability of professional Web portals in Europe is very low. Although there is coverage for the development of e-Skills and professional support, individual portals provide only partial information. Users have to change from one service to another to find an integrated path for their professional development.

As it can be seen, the dynamics of the labor market both nationally and internationally depend entirely on the good communication of information related to profiles, skills, competences and knowledge. In the EU, having 24 official languages, everything points to the fact that common terminology should be used to guarantee the exchange of information between job-seekers and employers. However, despite local and global efforts, many stakeholders (job-seekers, employers, employment services, employment portals, educational institutions and training centers) do not know the European frameworks and standards and do not recognize them when they are asked about them. For this reason, we conducted a survey of 97 experts to analyze the perception of e-CF and other European initiatives. Surprisingly, more than half thought they lacked information and 77% admitted not knowing any curriculum mapped with e-CF or with ESCO. The survey also found that there are important differences between supply and demand in certain areas, such as software (30.3%), management (29.2%), cybersecurity (15.7%) or cloud computing (14.6%). These gaps give an idea of the need to apply the standards both in the field of training to detect those competences on which the new training courses should be based and also so that candidates who have a certain profile can self-assess their competences and verify if they meet the requirements of a certain job.

Although e-CF was confirmed as a European standard by the European Committee for Standardization in 2016, the Council of European Professional Informatics Societies (CEPIS) identified that there was a lack of information provided to employers and other potential users of e-CF. The promotion, provision of information and employment assistance to understand how e-CF can be used is a need that has not been identified either by the EC or by the European Standards Organization. As an organization whose mission is to improve and promote a high level among information and

 ISBN: 978-1-61208-735-1

technology professionals in recognition of the impact that information technology has on employment, business and society, CEPIS also advocates that e-CF should be established progressively in member states to promote the professionalization of ICT in Europe.

The present work aims to contribute to supply the deficiencies mentioned above through the implementation of competence maps of training courses that try to link the academic world with the labor world. This union constitutes a novel approach never before treated and represents the first step for a pioneering attempt to publicize European standards and adapt them definitively to the Spanish educational system.

III. BENEFITS OF THE MAPS

Considering the previous contributions to the scope of the present work, its innovative effect could be broken down into the following points:

- Understand the basic characteristics of the main European competence frameworks to subsequently be able to identify their relationship with the labor market and with the field of education.

- Provide a common European language for the ICT job market in terms of competences, skills and proficiency levels required by professionals in the sector. In this way, all stakeholders could have a common shared reference.

- Help to define:
    - Jobs, offers and hiring needs, and other competence specifications.
    - Training courses, qualifications, certifications and higher education programs.
    - Career plans and professional development needs.
    - Plans for formal and non-formal education.
    - Analysis of competence improvements and training needs at an individual or global level.

- Allow mobility through the European job mobility service, improving the transparency and comparability of qualifications across Europe, as differences between the education systems of member states make it difficult for employers to identify the skills and qualifications that a person has obtained in another EU country.

- Help the training centers by describing the learning outcomes, as these are defined in terms of knowledge, skills and competences. This shared terminology facilitates dialogue between the labor market and stakeholders through different sectors and borders. In addition, it allows to understand the development of emerging skills in an international context, and to be able to communicate in the same language as employers:
    - Employers will verify the suitability of a candidate for a job based on their qualifications.
    - Educational systems will be able to obtain feedback on the needs of the labor market, identify skills gaps and adapt their qualifications accordingly to meet employment needs.

- Improve the efficiency of human resources departments, providing a connection between jobs, skills and qualifications:
    - The competences can be used to describe jobs, competence specifications and descriptions of professional development needs.
    - Competence levels can be used to provide detailed profile specifications.
    - The competences are related to jobs, which allows to focus efficiently on the selection of personnel, hiring, and collaborations.
    - It makes it possible to measure the skills deficit and the short and long-term planning, to evaluate and budget the educational and training needs of the staff.

- Help employers to:
    - Understand the knowledge, skills and competencies that people have to obtain through education, training or work experience.
    - Express what they expect from their employees with knowledge, skills, competences and qualifications.
    - Find the right person for a job.

- Help job seekers to:
    - Understand what employers need.
    - Understand how they can develop their careers through lifelong learning.
    - Describe their knowledge, skills and competences in order to find the right job.
    - Self-evaluate to know what competencies have been acquired and which have not.

- Help employment services to:
    - Provide better online services to their users by improving the mapping of job seekers with jobs.
    - Communicate with their users in several languages.
    - Partner with other service providers and exchange information with them, to strengthen cooperation between public and private employment services, as well as training centers.

Table I shows an example of a competence map. The training course that has been analyzed is called “Master in software engineering for the Web”. It is offered by the University of Alcalá (Spain) and its duration is one year. The 80% of the course can be studied online. According to the table, the e-CF competences covered with the course are listed together with their correspondent proficiency level (from 1 to 5). If the competences from the ICT profiles are considered, we can see that the certificate covers different competences with different levels. Finally, the related ESCO occupations are also included at the bottom of the map. Note that sometimes the names of the e-CF job profiles are different from the names of the ESCO occupations.

 ISBN: 978-1-61208-735-1

TABLE I. EXAMPLE OF COMPETENCE MAP.

Competence covered with this certificate		Competence from the ICT Profiles			
e-CF competency	Level	SYSTEMS ANALYST	DIGITAL MEDIA SPECIALIST	DEVELOPER	SYSTEM ARCHITECT
A.5. Architecture Design	4	3			4
A.6. Technology Trend Monitoring	3		2		
B.1. Application Development	3	3	3	3	4
B.2. Component Integration	2			2	4
B.3. Testing	3		2	2	
B.5. Documentation Production	2		3	3	
B.6. Systems Engineering	4				
C.3. Service Delivery	3				
D.11. Needs Identification	2				
D.12. Digital Marketing	1				
E.5. Process Improvement	3	3			
E.8. Information Security Management	4				
ESCO Occupations		ICT system analyst	Digital media designer	Software developer	ICT system architect

IV. CONCLUSION AND FUTURE WORK

It is expected that this work will have a significant impact in its field, due to the development of competence maps, starting with higher education, and due to the implementation of the training course that will reveal the main competence European frameworks to the main stakeholders. The use of these standards will improve the relevance of the mapped training programs at the international level, since they will follow the same reference that is beginning to be established in the rest of the world.

The results of the project will make possible to address technological transfer actions towards companies and external entities in which work connections already exist in the following areas:

- Competence analysis guide for personnel, adaptation to the professional profile and organization of support for the internal career plan and training in human resources related to ICT: collaboration and contacts with Exin Consulting [14], Human Resources Department of MadridDigital [15], etc.
- Specialized training for consulting services, public entities and training centers, with existing contacts with the computer services department of the University of Seville (Spain).

The proposed work will implement a social innovation process to engage people in the learning activities. In this regard, the authors will devote significant effort in engagement and dissemination activities, consulting with all relevant EU stakeholders in the research community, institutional actors in the member states, the industry, and public employment services, businesses and job-seekers representing end users.

The communication and dissemination strategy includes the following items:

- Developing courses
- Developing promotional materials: presentations, press releases, factsheets, posters, brochures, etc.
- Disseminating the results via online and offline communication channels.
- Feeding updates of the results on social networks
- Developing a website.

A possible future line of research deals with the development of certification competence maps. There are currently 2313 ICT certifications [16] from 161 different entities. This mapping would represent a very novel contribution because it would connect another fundamental pillar of the ICT sector with the European reference frameworks.

ACKNOWLEDGMENT

This work is supported by the Vice rectorate for Research and Knowledge Transfer of the University of Alcala (Spain) through project CCG2018/EXP-015.

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 ISBN: 978-1-61208-735-1

Mathematical Modeling Approach to the Design and Analysis of Measurement and Control Systems

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Abstract—**Mathematical modeling represents system behaviors in mathematical terms. In system analysis, a descriptive model can be done using different control laws or fitting experimental measurements or other empirical data. This work presents an analysis based on mathematical modeling as the behavior observation representations for measurement and control systems. Some adaptable control methods based on multi-function optimizations from the linear and nonlinear characteristic measurements became a step to ensure stable system performance. Developing a mathematical model for changing the regenerative parameters within the limit of the feasible structure is a synthesis of measurement and control systems. An application for calculating energy from power demand associated with the switching delays depending on the charge controlled capacitor properties is constructed. The process of developing a suitable mathematical model from experimental measurements and control gives the key for the principle practice modeling design system.**

Keywords- mathematical model; system analysis; measurement; control system.

I. INTRODUCTION

In the traditional measurement system engineering, the role of a model is not only important for advanced system design, but also to measure the viability and reliability of the system. Traditional model approaches to system engineering have always relied on mathematical modeling. Mathematical models are usually used in different engineering disciplines such as electrical engineering, computer sciences, nature sciences, or social sciences to explain how a system works and to predict the behavior in the future.

The energy resources in the world are exploited with the use of traditional energy, causing an environment problem as well as global warming. Renewable energy sources are clean and available in nature, but the problem is, it is difficult to use energy economically and efficiently. Reasonable exploitation and use of renewable energy requires a sustainable optimal synthesis method. The preferred solution is to select the optimal mathematical model for forecasting techniques. According to the classification criteria of mathematical models, nonlinear systems tend to be studied with strongly nonlinear models. There are two main approaches: the model free approach and the model based approach. The model based approach has a fundamental role in determining time, size and cause of a characteristic in a dynamic system operation. The model based approach is done by the structure of the model and the existing input-output relationships.

The model free approach is used in real time measurements and process history, when the model based approach is unavailable or not useful. In dynamic systems, the inner parameters of the system will modify its dynamics. If a characteristic property or parameter of the system from the standard condition changes, there are some blocking situations of disconnects between system components or structural damage inside. The pre-knowledge of a healthy system usually uses observer-based methods or parameter estimation techniques. However, some nonlinear characterizations might not be observed and estimated because of the inaccurate values of the physical variables or environmental conditions.

The nonlinear characteristic approach in a system is critical to the quality of measuring the production processing capability. This characterization is done by using a phenomenological or general basis function, which is the observed behavior of the system. This shows that changes in the inputs of a model affect the output, but sometimes produce un-observed states. Because the characteristics of each part or each component are completely different, from random fault as variations of supply voltage, temperature changes or inaccurate instrument reading, improving safety and reliability for the automatic recovery, a nonlinear system needs a specific control technique with a low cost and high effectiveness. Nonlinear characterization measurement can be suggested as a method in fault detection for operating constraints in process system than the corporation with the potential inaccuracy of the model or model mismatch. A mathematical model built from this characterization is to select in design and analysis the measurement and control system. The rest of the paper is structured as follows. In Section II, we provide an overview to improve the analysis and design approach with mathematical modeling. In Section III, an adaptive

 ISBN: 978-1-61208-735-1

development method based on control theory allows to develop simulation nonlinear characteristics as a virtual tool for ensuring stable system performance. The conclusion presents a collection from the series references for using mathematical modeling for design and analysis of measurement and control systems.

II. MAIN PROBLEM

In each structure system, the classification criteria are linear or nonlinear mathematical model, static or dynamic model, explicitly or implicitly calculated, deterministic or probabilistic model, deductive, inductive or floating model. This work concentrates on linear and nonlinear mathematical models. A mathematical model describes the system by establishing the relationship between the variables from a set of variables and equations. Some properties of the system are the set of functions between the different variables and building the equations of the described system.

A. Model based and model free

The first group is the model-based method, also known as knowledge based dynamic model. The behavior of the system when modeled as a set of differential equations is usually in state space form. The nonlinear state space model has the general structure:

$$\begin{cases} \dot{\underline{x}} = \mathrm{f}\left(\underline{x}, \underline{u}\right) & \underline{x} \in R^n,\ \underline{u} \in R^m \\ \underline{y} = \mathrm{g}\left(\underline{x}\right) & \underline{y} \in R^p \end{cases} \quad (1)$$

The measurement vector y is provided by the available sensors, and u is the control input vector, n, m, p are the dimensions of the vector x, u, y [10]. Under classical assumptions about control inputs, this general representation rewrites in an input affine form:

$$\begin{cases} \dot{\underline{x}} = \left(\underline{x}\right) + G\left(\underline{x}\right).\underline{u} & \underline{x} \in R^n,\ \underline{u} \in R^m \\ \underline{y} = \mathrm{g}\left(\underline{x}\right) & \underline{y} \in R^p \end{cases} \quad (2)$$

This model retains the nonlinear global behavior of the system while benefiting from interesting results in nonlinear control theory. A further step towards simplification is to linear equation (2) around an operating point or a reference trajectory. The linear model has the form:

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx \end{cases} \quad (3)$$

Where A, B, C are possibly varying time. We suppose A and B are controllable for the linear conditions in which the criterion optimization stands. The computation to solve around equilibrium uses the matrices between themselves as takes into account the nonlinearities of function f. g corresponds to the global behavior of the system.

Developing an improved mathematical model is estimating the accuracy of the estimated parameter and identification as characterization of the model system. To obtain the suitable mathematical model for the system with special characterizations by all techniques in computer sciences, an example is presented in [8].

A dynamic system model can be categorized by many factors, such as genetic and non-genetic aging factors. Genetic factors can not be easily controlled, while non-genetic can be controlled and include poor maintenance, high loads and stress in the operation of the system. Some parameters make the model can't be observed and controlled in the domain stabilization system. These parameters need to be identified to ensure an accurate action processing or make the move to protection mode and automatic mode. The algorithm for estimate these parameters is based on aging, such as mechanical, electrical and structural conditions, which are important for most of existing model designs. Beside the estimation parameters, processing signal by image is often used in any fields where the quick identification of an object is necessary. This work is as empirical model for the model based software and system engineering.

The model free approach is also used when no explicit dynamical model of the control system is available. It exploits measurements acquired in real time, or available in a previously constructed database, using the behavior of the signal model. Some nonlinear characterizations in the system might not be observed and estimated. The predicted solution is suitable operating in the control system. For the vehicle system, the model free approach is preferred for the trajectory control, represented by differential equations or difference equations. The model free approach is useful for a scenario in which the system depends on other random variables relating inputs to outputs for the role of control. An example of a model free approach is as follows. A system presents a model free by general state equation [10]:

$$\dot{\underline{x}} = \left(\underline{x}, \underline{u}\right) \qquad \underline{x} \in R^n,\ \underline{u} \in R^m \quad (4)$$

The output of this system y, $y \in \mathrm{R}^{\mathrm{m}}$ that vector output can be rewritten in the form:

$$\underline{y} = (y_1, y_2, y_3 \dots, y_m) \quad (5)$$

$$\underline{y_i} = h_i(\underline{x}, u_1, u_2, \dots, u_m) \quad \mathrm{i} = 1 \text{ to } \mathrm{m} \quad (6)$$

The output components of y are analytically independent, the state components *x* and the input components *u* are the function of the output components and a known number of their derivative, written as follows:

$$\begin{cases} x_i = \Phi_i(y_1, y_1^{(1)} \dots, y_1^{(\mu_i,1)}, y_2, \dots, y_2^{(\mu_i,2)} \dots, y_m, \dots, y_2^{(\mu_i,2)}) \\ u_j = \psi_j(y_1, y_1^{(1)} \dots, y_1^{(\upsilon_j,1)}, y_2, \dots, y_2^{(\upsilon_j,2)} \dots, y_m, \dots, y_2^{(\upsilon_j,2)}) \end{cases} \quad (7)$$

The functions $\underline{\Phi}$ and $\underline{\Psi}$ are identified by the equation:

$$\dot{\underline{\Phi}} = f\left(\underline{\Phi}, \Psi\right) \quad (8)$$

Consider a nonlinear system whose discrete time dynamics from an initial state are given by:

$$\underline{X_{k+1}} = \underline{X_k} + \mathrm{f}\,(\underline{X_k}, \underline{U_k}) \quad (9)$$

with $\mathrm{k} \in \mathrm{N}$ where $\underline{\mathrm{X}_\mathrm{k}} \in \mathrm{R}^{\mathrm{n}}$, $\underline{\mathrm{U}_\mathrm{k}} \in \mathrm{R}^{\mathrm{m}}$, f is a smooth vector field of $\underline{\mathrm{X}_\mathrm{k}}$ and $\underline{\mathrm{U}_\mathrm{k}}$ is, respectively, the state and the input vectors of this system at time k. We suppose here that each input has an independent effect on the dynamic state:

$$\frac{\partial f}{\partial u_i} \neq \frac{\partial f}{\partial u_j} \quad i \neq j \text{ with } i, j = \{1,\ldots, m\} \qquad (10)$$

The discrete dynamic model in a nonlinear system can be rewritten as:

Model continue → Discretion → Discrete Model

$$\dot{\underline{X}} = f(X, U)\underline{X}_{k+1} \quad \Longrightarrow \quad \underline{X}_k + f(\underline{X}_k + \underline{U}_k)$$
$$\exists Y_k |\, Y_k = h(\underline{X}_k) \qquad (11)$$

With $k \in N$ where $\underline{X}_k \epsilon R^n$, $\underline{U}_k \epsilon R^m$

$\underline{X}_k$: is in respect to the state vector of this system at time k.

$\underline{U}_k$: is the input vector of this system k to k+1.

f: is a smooth vector field of $\underline{X}_k$ and $\underline{U}_k$.

$\underline{Y}$: the output vector measurement.

The mathematical model by state equation (11) is structured from the output function, the state component and input component. It makes more clearly about the characteristic set to function dynamic system, using model output obtained by simulation and prediction when the process noise enters the system. Input noise is an important role defined non-functional properties in a systematic manner when not well established domain. The simulation is developed by the non-functional properties tool under the function properties parameters from the model free method. An application for building using the model based approach is shown in references [8][9], in which energy performance diagnosis is done based on a mathematical model from non destructive measures, inverse method and artificial neural networks. Another application for associated model free can be found in reference [10,] that improves the model based approach by a dynamic model with characteristic matrix fault effect to flight trajectory. These works provide an overview in using a model as the best way for measurement and control advance methods.

B. Maintaining the measurement and control system

Modern control theory approaches not only the model based approach but is also based on different methods like the model free approach in which the output has a characteristic prediction of the input. Analytical redundancy means to exploit mathematical relations between measured or estimated variables to detect possible dysfunction. This should be understood as knowledge based dynamic model [10]. Residual generation uses a model of the system in which the control inputs sent to the actuators and the system outputs as measured by the sensors injected to predict the behavior of the system, or part of it, and compare this prediction to the actual action. The associated algorithms are located functional and non-functional properties of models to performance benchmarking and optimization**.**

Based on the difference between performance level-PL and safety integrity level SIL, each architecture model is associated with three parameters: frequency and duration of exposure Fr, probability of an event occurring Pr, probability of avoiding or limiting the harm Av [11]. For the particular applications, the model choices such as thermal and ageing models are required by prior experience using the equipment in process industries where the transformer thermal loss of life related with changing the regenerative parameters within the limit of the feasible structure [3]-[6]. Thermo physical parameters are the important parameters in the transformer thermal for building, vehicle, etc. Building a model based on [4] by chosen thermal, loss of life model, the load and ambient temperatures are the factors for long term planning to realistic conditions. A method and a model presented in [3] show model parameterization by the variability of operating conditions to achieve nonlinear loads. For insulating materials, the degradation model Arrhenius from the chemical kinetic law of Arrhenius presented in [5] to obtain some results in [6].

III. APPLICATIONS

Some approaches to system design and analysis selected mathematical models, such as the works illustrated in [1][2][7]. A reconstruction performance of the process analysis is shown in [1] by computation tomography. An acoustic emission technique is applied for ceramic material in [2]. A nondestructive control method to have the characterization put in for plastic composite is presented in [7]. The way to ensure stable system performance becomes a step in the control based mechanism such as the energy from the associated power demand [8]-[10]. An unmanned vehicle as drone in a complex system has been applied as a mathematical model approach and user centered methodology in Samanta method for the designed human factors based on the analysis and development of a specific Web based tool [12]. This methodology also involved the model free approach for different support stages. To achieve the innovation criticized for expected structure achieved on dynamic switching, the nonlinear differential equation expressions based on the form fracture cracks growth structure and data prediction tendency levels are used [13]. Figure 1 illustrates the idea of building smart models based on mathematical modeling for design and analysis of measurement and control system.

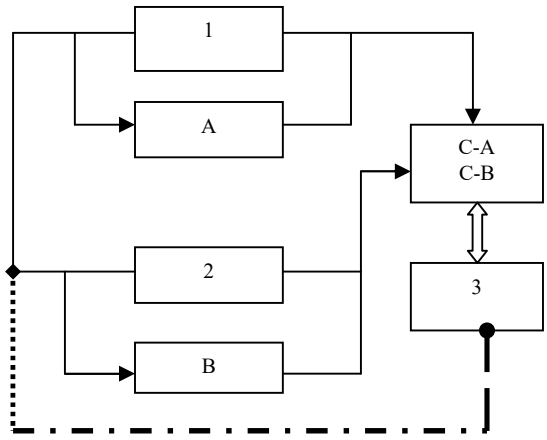

Figure 1. Example of the framework for developing a mathematic model.

1- The model free approach as the tendency equation with nonlinear dynamic equation for control system.
2- The model based approach as the database theory with the foundation database.
C- Connection equations.
C-A – Following the design and control prediction, the strategy dynamic trajectory path is calculated.
C-B - The approximate equivalent analytical solution based on foundation database.
3- States transforming equation to the adaptive smart model.

IV. CONCLUSION

Mathematical models are composed of relationships and variables, which can be described as operators and parameters, or multi-functions, according to their structure. In a complex dynamic system, experimental measurements and control with linear and nonlinear characterizations leads to important advances. Such as the useful theories, are developed a suitable mathematical model in the process system to solve the mismatch model problem. Training and tuning to obtain the model evaluation provides a given mathematic model that described the system accurately. The idea of this paper is a new solution for developing a mathematical model based on smart model adaptive from regenerative parameters within the limit feasible structure by renews switch delay connections. The future work continues present more detail about the floating model in catastrophe theory to obtain natural dynamic nonlinear equations.

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